

Inland Pacific Northwest Pasture Calendar



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Inland Pacific Northwest Pasture Calendar



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This bulletin is comprised of two major sections, e.g., Introduction Chapters and Appendix Chapters. The eight Introduction Chapters were co-authored by all team members. Authorship is designated for each of the 17 Appendix Chapters. Appendix Chapter 5 is reprinted by permission from the University of Idaho Extension.

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Introduction Chapter 1



Introduction to the Inland Pacific Northwest Pasture Calendar

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Introduction

The Inland Pacific Northwest (PNW) region, historically referred to as the 'Inland Empire', extends from the Cascade Mountains in the west to former Glacial Lake Missoula in the Rockies in the east and from the Canadian border in the north past the Snake River Canyon in the south. This area is about 36,000 square miles (93,078 km²), or about 23 million acres (93,078 km²). The greatest agricultural enterprises are hay (from various forage species), irrigated and non-irrigated grassland pastures, rangelands, and livestock production. It is also home to numerous wildlife species and flyways for migrating birds.

The Inland PNW Pasture Calendar is designed to be a comprehensive guide for improved grassland management in support of forage-livestock systems. Applying the principles described will lead to improved regional economic, ecological, and social sustainability. This publication describes the opportunities and challenges of sustainably raising harvested and grazed forages and developing forage-livestock systems in this incredibly diverse environment. This 'Calendar' bulletin is based on the principles described in the Western Oregon and Washington Pasture Calendar (Fransen et al., 2017), but specifically for the Inland region. The Inland Empire has vast differences in environmental conditions, land, capital, and natural resources. The goal of this publication is to promote sustainable forage management and improve water and air quality, through reduced overgrazing. When adequate stubble height is maintained, pastures produce more forage, have fewer weed problems and require less frequent renovation. The goal is to improve pasture and environmental sustainability while providing animal products and higher quality of life for those who live there. The Calendar has been written and edited for the conditions of the Inland PNW region.

The Pacific Ocean and Cascade Mountain volcanos influence the climate and weather patterns originated from the west and northwest, and consequently the forage crops grown. The Cascade Mountains separate the westside, which receives abundant moisture from fall through spring, but very dry in summer, from the rain shadow, Inland region, which receives mostly winter rains and snows but also very dry in summer. Inland moisture varies by elevation, aspect, and other

conditions. The Cascades trap winter snowpacks for developed seasonal irrigation of pastures, haylands and other crops. Generally, the westside and Inland regions receive most of the moisture during winter and are dry during summer. Many of same forage crops are grown in both regions, but managers must select adapted species and management for their appropriate environmental conditions. Areas within the Inland region have experienced major flooding events in the past, e.g., Glacial Lake Missoula floods and the ancient Lake Bonneville flood. These floods helped reshape major portions of the Inland region. The Blue Mountains, near the Inland center, the Rockies to the east and the Cascades to the west, have created major differences in: elevation and exposure, deposits or removal of surface soils, differences in wind currents and moisture rain shadows, areas where there are long, frost-free growing seasons to areas where killing frosts can occur every month of the year, as well as differences in soil physical and chemical characteristics, and organic matter potential.

Inland region pastures have sustained domestic livestock and wildlife for centuries through diverse communities of perennial grasses, legumes, and other forbs. Although this publication is not focused on rangelands, which cover about 10,700,000 acres (43,301 km²) in the region, many plants are adapted to and used in both rangelands and grassland pasture communities. Many livestock producers in the region manage both native rangelands and improved pastures, recognizing their differences and managing each accordingly. One major difference is irrigation; the area within the Inland region that are irrigated pastures is approximately 660,000 acres (2,671 km²). Unlike the mid-west, east coast and southeastern U.S., the Inland Empire receives very little precipitation during the growing season. Most of the region's irrigation water is derived from mountain snowpack, through spring and summer melting. To achieve season-long water for irrigated pastures, a series of reservoirs and canals have been developed and maintained by irrigation districts to supply water for pastures and many other crops.

The Calendar is designed to help you correctly time management activities for your pastures. Note that all three state Calendars start in early September when perennial grasslands prepare for the next year's growth. At this time, grasses begin growing new, white roots and producing new growing points called apical meristems. The apical meristems eventually turn into tillers that produce forage and roots for the next annual growth cycle. The annual cycle of forage growth is divided into

¹Inland Pasture Calendar team members by organization, location and email address are listed at the end of this Introduction Chapter 1.

“Growth Periods” numbered 1 to 10. For each growth period we explain what the forage crop is doing and provide management recommendations. The timing of a growth period will depend on where you are located in the region. The region is divided into Major Land Resource Areas (MLRA's) developed by the USDA Natural Resources Conservation Service (NRCS), and estimated calendar dates for each growth period are provided for each MLRA.

The Inland region is suitable for some warm-season perennial grasses, but far fewer species than of the cool-season perennials. The warm-season perennials generally flower after the summer solstice while the cool-season perennials flower before June 21. Pastures are managed for direct harvesting by grazing animals. In that case, flowering tillers are seldom observed in the field because they have been consumed by the grazers.

Selection of pasture plant species and proper grazing systems are often dictated by the physical features and environmental factors within a MLRA. These constraints are characterized for each MLRA. By basing the Calendar on growth periods within each MLRA, fewer discrepancies in pasture growth periods by MLRA are found among the three states. This provides advantages to producers and planners and removes redundancy across the diverse region.

How to use the Calendar

1. Within the selected PNW state (Chapter 5), identify the most appropriate MLRA for the location of interest (Chapter 4).
2. Each MLRA has a unique color in the Calendar and is separated based on pasture growth from natural precipitation, “average / dryland”, or if pastures are provided supplemental irrigation water, “optimum / irrigated” (Chapter 7).
3. Follow the 10 pasture Growth Periods (Chapter 6), which also are in unique colors, and designate expected pasture growth and development for ‘average’ bi-weekly schedules starting in September (Chapter 7).
4. Review / compare and contrast the pattern of growth in those pastures of interest with that expected from Chapters 6 and 7.
5. Following these steps, read Chapter 8 and focus on the four components discussed. We’ve included ‘things to avoid’ because those listed issues need to be kept in mind when making decisions.
6. The Appendix Chapters are written to supply answers to questions and enhance understanding or ‘why’ to questions when considering and reviewing pasture decisions. The Appendix Chapters are organized by: Forage and Livestock Integration, Agronomics, Livestock, and Systems.
7. The final Appendix Chapter is the Index.

Summary

This publication shows how pastures grow in the Inland region; that overgrazing provides no advantages, but rather results in unsustainable systems. Appendix Chapters provide key information on grass / legume / forb species, how pasture species grow and regrow, soil nutrient management and organic matter, grazing philosophies and systems, matching grazing needs for pasture production, and forage-related animal health issues. Learning these key principles and following best management practices described will lead to improved sustainability of forage-livestock systems.

Project Team

The Inland Pacific Northwest region is unique in its diversity, beauty, and people. The project team wrote the successful Western Sustainable Agriculture Research and Education (WSARE) Professional Development Program (PDP) proposal, reflecting the Inland region in all aspects. The team met numerous times at different locations in the development of the Calendar and the supporting documents. We conducted a four-webinar series, which have been edited and will complement this bulletin. The eight chapters in this Introduction should be considered as developed and written by the entire Calendar team membership. The following 18 Appendix Chapters will designate authorship and contact information. The following is the listing of the Inland Pacific Northwest Pasture Calendar members:

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Fransen, S., G. Pirelli, M. Chaney, and S. Robbins. 2017. The Western Oregon and Washington Pasture Calendar. PNW Bulletin 699.



Introduction Chapter 2

Terminology used in the Calendar

The following terms are used throughout this bulletin. These terms provide a context of understanding when discussing key principles and management of forage species in pastures.

Calendar — Refers to the Inland Pacific Northwest Pasture Calendar which includes the 14 Major Land Resource Areas (MLRA) and 10 Growth Periods of pastures for Idaho, Oregon, and Washington.

Carbohydrates — Plant foods, primarily fructans in grasses and starch in legumes. Fructans are sweet, and animals can sense their presence.

Cell wall constituents — Lignin, hemicellulose, and cellulose. These materials are created through photosynthesis and sugar metabolism. Cell walls provide the digestible energy for grazing animals.

Cool-season grasses — Grass species that begin to grow in the spring and continue growth as long as soil moisture and cool temperatures prevail. Their growth rate decreases during the hot, dry months of summer. Regrowth will begin in the fall if moisture is adequate. Cool-season grasses account for nearly all regional pasture grasses.

Crown — The transition zone between the roots and the aboveground portions of the plant. In this zone carbohydrates are mainly stored and where growing points are initiated.

Field Capacity — Percentage of soil moisture remaining after drainage has occurred and soil is capable of releasing moisture to forage plant roots.

Forbs — Often dicots, broadleaved plants without woody stems, perennial non-grass plants found in rangeland stands. Some forbs are poisonous to grazing livestock.

Growing point (apical meristem, “bud”) — Apical meristem is the point from which roots, leaves, stems, and seedheads grow. Intercalary meristems are located at the junction of the collar and the leaf blade and where leaves grow. They permit rapid regrowth of leaf tissue after grazing or cutting.

Growth Period — Distinctive growth of perennial cool-season grasses grown either dryland or irrigated over a continuous 12- month period.

Legumes — Annual or perennial dicots, broadleaved plants without woody stems with capabilities of symbiotic nitrogen fixation with the correct bacteria on root nodules in soils.

MLRA — Major Land Resource Area. Refer to USDA-NRCS Agricultural Handbook 296. <https://www.nrcs.usda.gov/resources/data-and-reports/major-land-resource-area-mlra>

Plant food reserves — Sugars (carbohydrates) that provide energy for plant growth, regrowth after harvest, and winter survival. In grasses, reserves are stored mainly in the lower stems and also, if present, in the corms. Small amounts of storage carbohydrates are also found in roots. In contrast, legumes store sugars as starch in the crown, stolons, and roots.

Rhizome — An underground stem composed of nodes and internodes. Internodes provide carbohydrate storage, and nodes are the sites for root and shoot development.

Root — The underground portion of the plant. Each grass tiller has its own roots. Roots physically anchor the tillers and transport water, nutrients, and essential minerals. Grass roots store small amounts of carbohydrates while legume and forb roots large amounts of carbohydrates.

Stolon — An aboveground stem composed of nodes and internodes. Internodes provide carbohydrate storage, and nodes are the sites for root and shoot development.

Stubble — The remaining plant material after grazing or cutting. For cool-season bunchgrasses, the recommended 3 to 4 inches (7.5 – 10 cm) above the soil surface. Stubble is one of the main areas for carbohydrate storage, which sustains the plant through periods of seasonal dormancy and reinitiates growth after forage removal.

Tiller — The basic unit of the grass plant. A tiller consists of an aboveground stem, including leaves and perhaps a seedhead, and its attached roots below ground. Tillers with seedheads are called reproductive tillers, while tillers that produce only leaves are called vegetative tillers. Each tiller is joined at the base to other tillers to form the grass “plant.” Therefore, the single “plant” that is seen in the pasture is actually a grouping of tillers that share resources such as water, nutrients, and carbohydrates. Each individual tiller lives an average of 1 year, although some can live for 2 to 3 years.

Warm-season grasses — Grass species which produce forage growth during the hotter, summer pasture season. These species start growth later in the spring and end sooner in the autumn than cool-season grasses.

Introduction Chapter 3



Factors Controlling Perennial Forage Growth

Inland pasture and forage growth is controlled by environmental, plant physiology and morphology, and management factors. This chapter highlights those influences on forage growth, development, production, and survival.

Environmental factors

Major environmental factors that affect perennial forage growth include daylength (photoperiod), air temperature, soil temperature, soil moisture from precipitation and supplemental irrigation, and soil nutrients.

Daylength (Photoperiod)

Daylength includes not only hours of light per day, but also light intensity and light quality (wavelength). In the spring and fall, the tilt of the Earth relative to the sun changes light intensity and wavelength. These changes signal the plant to produce new roots and/or new growing points that can develop into reproductive or vegetative tillers. New roots and vegetative tillers are produced in both the spring and the fall. Most reproductive tiller apical meristems are produced in the fall.

Partitioning of photosynthate (sugars) and development of structural carbohydrates (fibrous cell wall constituents) depends on daylength and changes as the season progresses. Partitioning to stem bases and roots increases as photoperiod decreases in the autumn. Levels of plant sugars generally are lowest during summer and are higher in the spring and fall. Plant fiber levels increase as the plant matures.

Air and soil temperature

Air temperature is directly related to the amount of sunlight intercepted by the earth. However, soil temperature—not air temperature—controls the growth rate of plants. Since soil temperature is rarely measured, average daily air temperature is used to estimate soil temperature at 2 to 4 inch (5 – 10 cm) depths, the standard shallow soil depth where forage growth begins (<https://www.weather.gov/informationcenter>).

Visible cool-season perennial grass growth begins in spring, Growth Period 5a / 5b (Introduction Chapter 6), when average daily air temperature reaches approximately 41°F (5°C) (Chatteron et. al., 1989). Growth increases rapidly, reaching a maximum photosynthetic rate in the range of 68 to 77 °F (20-25 °C), Growth Periods 6a / 6b. In cool-season grasses (C3 plants), photosynthesis is reduced at temperatures above 30 °C (86 °F) due to increased photorespiration. Growth ceases above approximately 90 °F (32 °C), generally Growth Periods 7 - 10. Reducing plant canopy temperature through irrigation can extend somewhat the air temperature range for growth.

In the spring, air temperatures are often below the optimum for tiller growth. Roots, however, will grow at lower temperatures, if adequate moisture is available in dryland pastures or when pastures are irrigated, Figure 1, in Growth Period 5a. Thus, they can be very active, even when it seems the plant is not actively growing above ground. Root growth precedes above-ground growth in the spring and fall, persisting in the fall until Growth Period 4, Winter Dormancy.

Soil temperature is also related to the amount of sunlight available. However, soil cools and heats more slowly than air, so it acts as a heat sink, “storing” and “releasing” heat throughout the day and the season. As a result, soil temperatures lag air temperatures and can be affected by warm or cold rains. In the spring, the soil is cold and warms less quickly than the air; in the fall, the soil is warm and cools more slowly than the air.

Perennial forage legumes are an important component of Inland perennial grass pastures for multiple reasons: 1. cool-season grasses produce more biomass in spring and fall while comparatively, legumes produce more biomass during the warmer months, 2. legumes, with active rhizobia, should fix atmospheric nitrogen to sustain growth for both species, and 3. both should provide adequate yields of high quality forage dry matter for grazing during active growth and partially stockpiled into transition dormancy periods, e.g., Growth Periods 4 and 10. Perennial pasture legumes require higher soil temperatures to initiate each growth phase (Fransen and Griggs, 2010), with growth beginning at an average temperature of approximately 52 °F (11°C). Growth is reduced significantly at temperatures below 70°F (21°C) (Cralle and Heichel, 1982). Nitrogen fixation, a key reason to interplant with grasses, is particularly sensitive to low and high soil temperatures. Low temperatures delay root hair initiation and infection resulting in decreased nodulation and nitrogenase activity by 24 % and 75% at rooting temperatures of 55 °F (13 °C) and 46 °F (8°C), respectively (Cralle and Heichel, 1982). They found soil temperatures below 46°F (8°C), inhibited nitrogenase activity completely. Alfalfa nitrogenase activity increased sharply when soil temperatures ranged from 68 °F (20 °C) to 95 °F (35 °C) then dropped dramatically at 104 °F (40 °C) and were completely inhibited at 113 °F (45 °C). Alkaline soils, predominately found in the Inland region, as well as acid soils, tend to reduce nitrogen fixation in many forage legumes (Burton, 1972). Maintaining healthy soils through improvements in water quality, reduced soil erosion, building of soil organic matter and selection of adaptable / productive forage species are keys to both grass and legume sustainability.

Two regional sources for agriculture-based temperature data are: Agrimet, for Idaho and Oregon, and WSU Ag Weather Net in Washington. Weather stations are scattered throughout the agricultural region with the

intention of providing more accurate information and conditions for frost protection, growing degree days, length of growing season, natural precipitation, and aid in irrigation scheduling (see Appendix Chapter 15 for more details).

Soil water availability

Water is essential for cooling the plant and for internal movement of nutrients and sugars. Water is absorbed from the soil through the root system. Soil nutrients flow into the plant with the movement of water.

Grasses grow best when the soil is near field capacity (like a moist sponge) and will go dormant when they reach the wilting point. Once they become dormant, grasses require large quantities of water to start regrowing. Because of the lack of water in early fall, plants may show little aboveground growth even when temperatures are in the optimum range. However, new roots require relatively less moisture and can start growing while the plant top still looks dormant.

Nutrients

Nitrogen, phosphorus (P), and potassium (K) are the major nutrients required by Inland pasture grasses. Sulfur (S), calcium (Ca), and magnesium (Mg) also are essential. Appendix Chapter 5 provides an in-depth discussion of soil nutrient management in the Inland PNW.

Root and bud growth is directly related to availability of these six nutrients. In addition to these macronutrients, the micronutrients boron (B) and molybdenum (Mo) is needed by legumes. Mo availability is less available to forages at low pH levels, and liming can increase its availability and improve legume growth and nitrogen fixation.

If any of the essential nutrients are below required levels, plant growth will be reduced in spite of optimum light, temperature, and water conditions. Conversely, excess nutrients can also reduce plant growth. The Inland Pasture Calendar is based on the assumption of average / adequate soil nutrient status—neither too high nor too low (Appendix Chapter 3). Soil testing is the recommended method to monitor deficiencies or excesses and recommended applications of soil nutrients. Tissue testing is also a valuable tool.

The timing and number of nutrient applications will influence uptake and plant tissue nutrient concentrations. Nutrients are best applied in split applications, preceding periods of expected forage growth. For example, applying many of the needed nutrients in the spring in one or two applications will fuel rapid growth in spring and summer. Applying excess nutrients, e.g., nitrogen, in the fall can lead to forage winter-kill because plant continue to growing in Growth Period 3a / 3b rather than transition into Growth Period 4, winter

dormancy. Excess nutrients can increase problems of pollution through runoff or leaching.

Climate zones

The Inland region is comprised of 14 Major Land Resource Areas (MLRA; Introduction Chapter 4), which help form the basis for the pasture Growth Periods for each state as show in Introduction Chapter 5. People who live and work in this region quickly recognize the diversity of climate and weather patterns within an MLRA. These factors all impact what forage species will grow, when they will grow, limitations to growth and understanding what should be avoided during a Growth Period (Introduction Chapter 8).

Annual pasture growth cycle

To properly manage perennial grasses, it is essential to know how they grow. The basic unit of a perennial grass plant is the tiller. Each tiller consists of an aboveground stem, including leaves and perhaps a seedhead, and its attached roots. Tillers are joined at the base to form the grass “plant.” Therefore, a single “plant” is actually a grouping of tillers. Young grass tillers require a steady supply of nutrients and protection from stress. The number of tillers formed depends on soil nutrients, moisture, temperature, and previous pasture management.

The majority of new cool-season grass tillers are formed in the fall, when the apical meristem (“growing point”) is formed, and new roots start to grow. At this time, stand density increases, thereby competing with weeds while maintaining a productive pasture.

A secondary period of root growth and tiller establishment occurs in early spring. These new tillers usually are not noticed until midspring, when growth accelerates (Figure 1). Because of this burst of spring growth, this period traditionally has been thought of as the start of the forage or grass year.

However, based on what we now know about perennial cool-season grass tiller growth (Figure 1), fall should be considered the start of the forage year or the beginning of the Pasture Calendar (Fransen et al., 2017). For perennial forage legumes, the bulk of annual growth occurs in late spring to summer, when temperatures have warmed and light competition with grasses is reduced. Perennial warm season grass annual growth cycle differs greatly in the Inland region than either cool season grasses or legumes. Grass growth starts slowly after the spring flush of cool-season grasses, Figure 1, increasing rapidly by mid-summer, which is sustained until early fall when transitioning into dormancy. Perennial legume, cool and warm-season grasses are fully dormant during the winter Growth Period 4. All forage species are dependent upon stored carbohydrates during winter dormancy for survival and spring growth.

Nutrients for tiller growth

In addition to roots and an apical meristem, each tiller has vertical leaves, which capture sunlight to produce simple sugars, such as glucose and fructose, and more complex carbohydrates, such as fructans and starch. The bottom 3 to 4 inches (7.5 - 10 cm) of the tillers are the primary location of carbohydrate storage in cool-season bunchgrass species.

During the fall period of peak tiller production, nutrients are supplied from storage at the base of the previous season's tillers. Often, these older tillers are dormant and brown at this time of year. They aren't dead, however, and their storage function is critical. They also provide physical protection for new tillers.

Stored fructans in cool season grass stubble are sweeter than other carbohydrates and are preferred by grazing livestock. Fructans are also critical for long-term plant survival during periods of dormancy and regrowth. Overharvesting grass stubble will degrade the pasture over time. As tillers age, nutrient flows shift from older to newer tillers. Following the analogy of the apartment house, if new tenants don't move in as previous tenants move out, rental income will be insufficient and building maintenance will suffer (Appendix Chapter 5). In legumes, the main storage carbohydrate is starch, largely stored in the crown and roots. Starch maintains legumes during periods of regrowth and winter dormancy.

Management factors

Pasture management is the art and science of working within the constraints of environmental factors and plant biology to produce abundant and nutritious forage for livestock. Additionally, proper pasture management will provide economic returns as well as environmental benefits to the producer and community. Key management factors include the following:

- Protect roots and soil from compaction damage caused by vehicles or livestock traffic, especially when soils are wet and easily rutted.
- Maintain prescribed minimum stubble heights throughout the year. If carbohydrate reserves in stubble are lost, tillers will be negatively impacted, which increases plant death risks in dormancy periods when climate extremes are most harsh. Reduced stubble heights through overgrazing will reduce snow capture and delay potential production during Growth Periods 5 and 6.
- Supply inputs, e.g., nutrients according to plant needs (determined by regular soil testing) and irrigation (if available) to support plant health and growth when opportunities in the Calendar are possible.

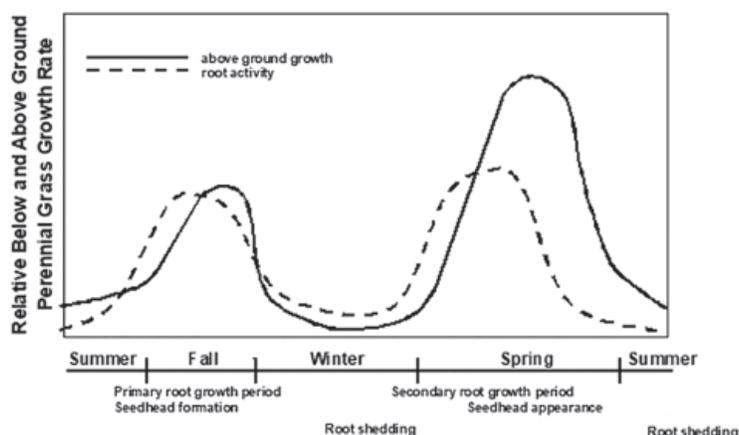


Figure 1. Renewed perennial cool-season grass growth cycle based on aboveground and root growth year-round.

- Provide adequate rest periods for pastures between grazing episodes. Big differences are found among cool and warm-season grasses in the number of leaves produced per tiller and the rate of leaf emergence. For example, perennial ryegrass (*Lolium perenne*) only produces three leaves before leaf one dies and leaf four emerges. Timothy (*Phleum pratense*) tillers will continually produce leaves and we have counted up to 18 leaves per tiller and seedhead to 8 inches (20 cm) at hay harvest or fewer prior to grazing.
- Prepare a sacrifice area, sometimes referred to as a 'utility pasture', for maintaining and feeding livestock when soils are saturated or when regrowth is inadequate for grazing. See Appendix Chapters 7 and 9.

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Introduction Chapter 4

MLRA Basics: Principles, Concepts, and Uses

Major Land Resource Areas (MLRA) are part of a USDA-NRCS land classifications system comprised of Land Resource Units (LRU), Major Land Resource Areas, and Land Resource Regions (LRR). This hierarchical system divides the country into smaller areas based on Physiography, Geology, Climate, Water, Soils, Biological Resources, and Land Use. The Inland Pasture Calendar has been developed for MLRA's in Land Resource Regions A- Northwest Forest, Forage and Specialty Crop Region, B- Northwest Wheat and Range Region, D- Western Range and Irrigated Region, and E- Rocky Mountain Range and Forest Region.

The project team selected this best approach to describe when, how and why pastures grow in the Inland PNW region. The MLRA ecoregions cross state lines, rivers and mountain ranges because they incorporate similar natural features and environmental factors that challenge producers and grassland managers region wide.

USDA Agriculture Handbook 296 – Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin describes the dominant characteristics of the 28 Land Resource Regions (LRR) and 278 MLRAs. <https://www.nrcs.usda.gov/resources/data-and-reports/major-land-resource-area-mlra>

The Inland Pasture Calendar makes recommendations for grazing management decisions by Major Land Resource Area (MLRA). The similarities in soils, climate, topography, vegetation, and other characteristic features within MLRAs make them logical subdivisions for the Inland Northwest.

This section describes perennial pasture grass growth by different developmental stages over a normal year managed as either dryland or “average” or irrigated, highly managed, “optimal or irrigated” by Major Land Resource Area (MLRA) in the three Pacific Northwest states. Many MLRA's extend through more than one state in the inland region. Several MLRA's will be found in all three states, suggesting many similarities among the PNW states for physical and environmental

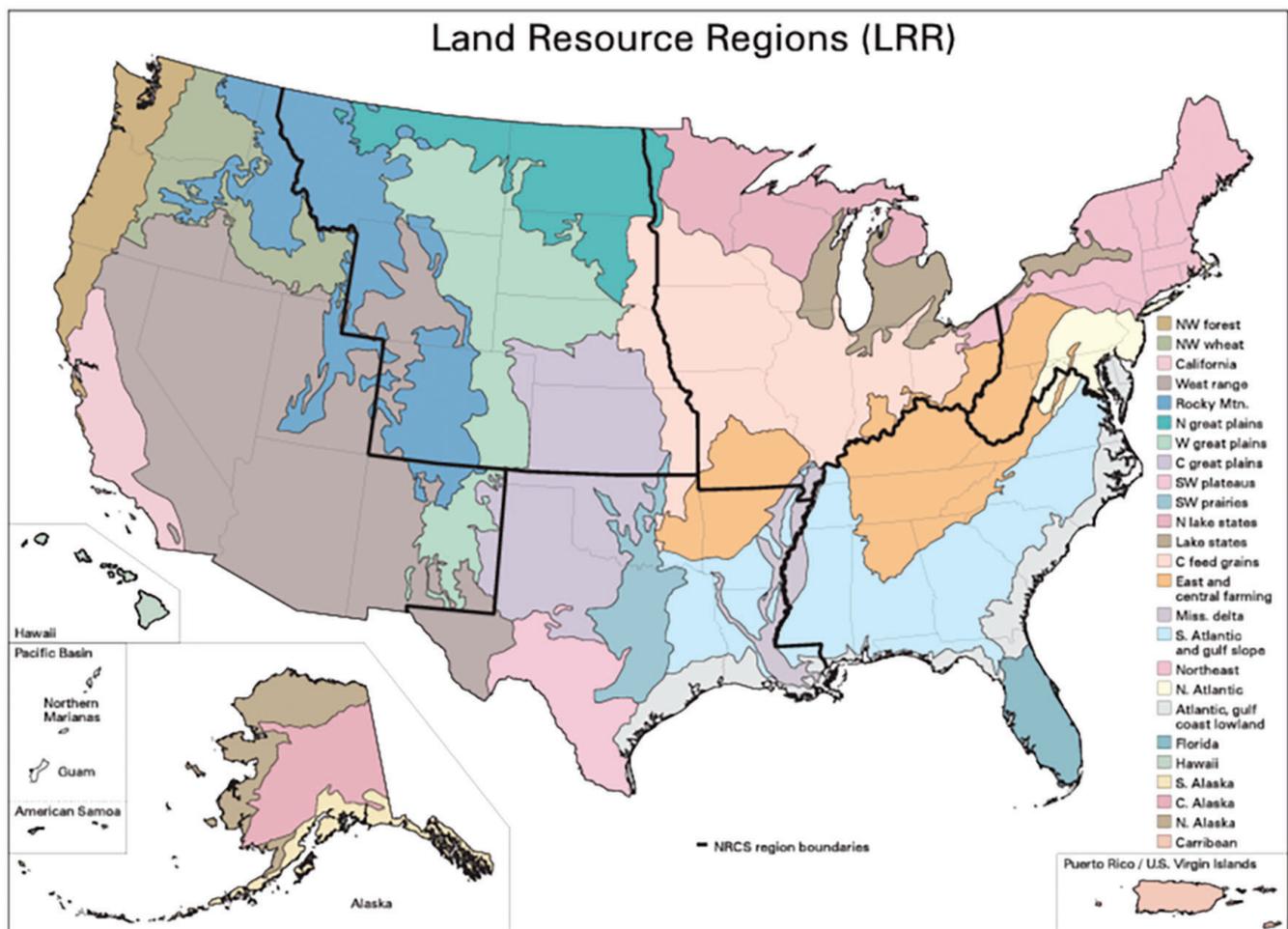


Figure 1- Land Resource Regions of the US

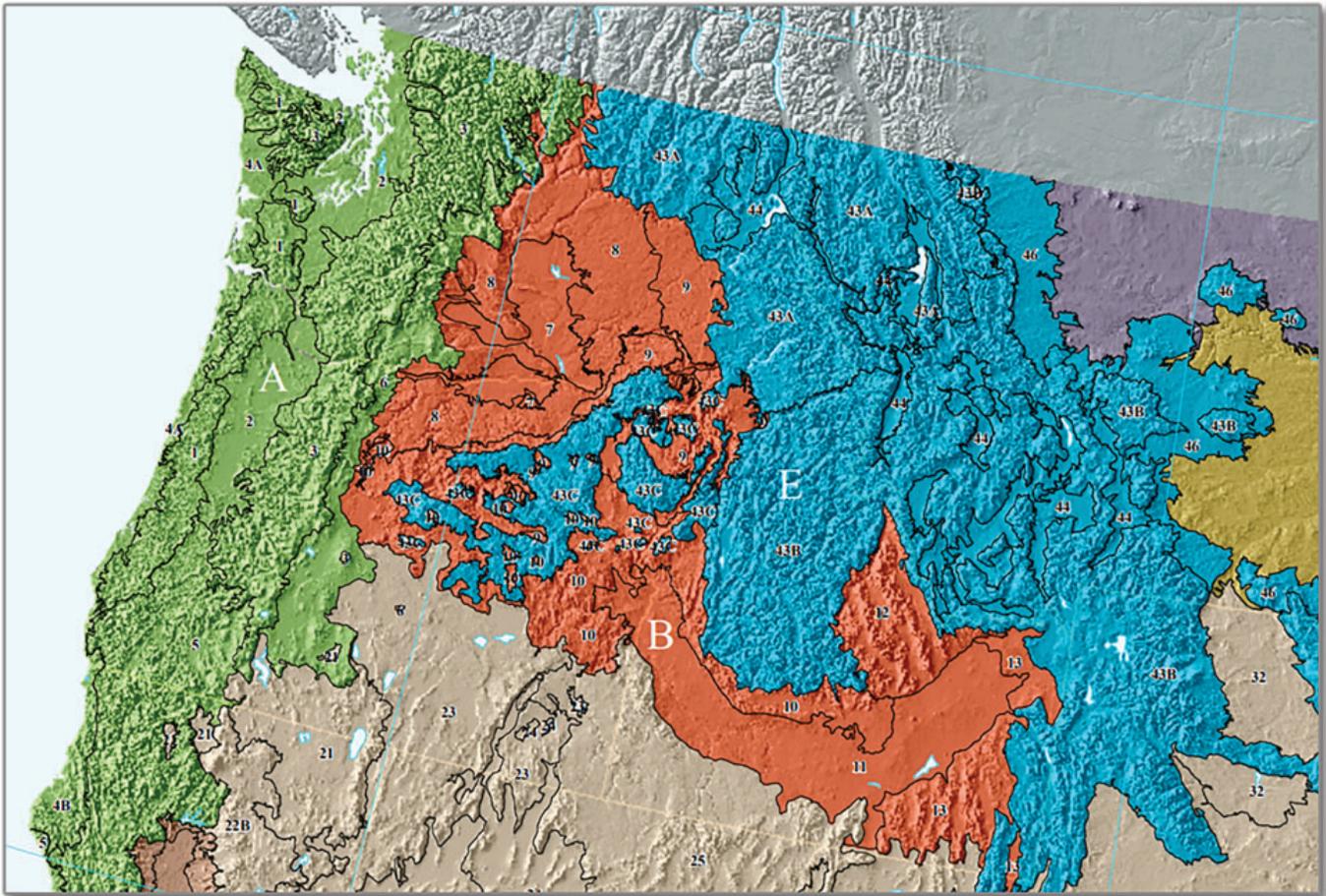


Figure 2 - Land Resource Regions for Oregon, Washington, and Idaho

characteristics. The focus of this Calendar is perennial grassland agriculture, which provides numerous services and sustainable economic enterprises for wildlife and citizens in the PNW. The information is divided into three major categories: Natural features, Environmental factors, and Challenges. Soil temperatures will be noted as much as possible because soil temperature is a major driver when perennial pasture grasses initiate spring growth or transition into winter dormancy.

MLRA 6: Eastern Slopes of the Cascade Mountains

Natural features: Created from ancient volcanos and soils often derived from pumice, MLRA 6 where natural grasslands are found intermixed in the forests and is a natural ground water recharge zone along on the eastern slopes of the Cascade Mountains. Most of the grasslands, however, are man-made through past logging and land clearing. Physically, MLRA 6 stretches from southern British Columbia into southern Oregon, following the Cascade Mountain east slopes. The area is split about equally between Washington and Oregon, relatively long and narrow north to south. Elevation ranges from about 900 to 8,000 feet (274 – 2,743 m) suggesting most

of the naturalized and tame pastures are found at the lower elevations since about 1/3 of the water used in this MLRA is for irrigation. The region also holds many of the storage reservoirs used for growing season irrigation needs in MLRA's 7 and 8 in Washington and Oregon plus MLRA 21 and 23 in Oregon.

Environmental factors: Perennial pasturelands are largely in the rain shadow of the Cascades where rainfall ranges about 15 to 45 inches (381 – 1,143 mm) per year with higher rainfall at higher elevations. Frost-free period ranges from 110 to 154 days with the longer growing season in the southern region. Even with a relatively good growing season, seasonal growing night and daytime temperatures are cooler than many other MLRA's. Snow accumulates from November through March with April mostly snow free. Soil orders are largely younger soils, such as Inceptisols, to grassland soils, such as Mollisols. Because soils are young and largely derived from forests, soil series are lower in organic matter and acidic compared to other MLRA's in the PNW.

Challenges: This MLRA is challenging when growing perennial pastures and native grasslands because elevation differences influence the amount of natural

precipitation and length of frost-free period. The lower elevations, where most pastures are, receives between 15 to 25 inches (381 – 635 mm) of precipitation annually so moisture, like in many of the MLRA's of the Inland Northwest, can be a limiting factor. And, like the other MLRA's, precipitation comes mostly in winter and spring leaving summer and early fall mostly arid. And although most pastures are in the warmer, lower elevations of the MLRA it's not uncommon for them to be in cold air drainage valley bottoms. Nighttime and early morning temperatures in these drainages can be several degrees colder than the surrounding area. Pastures arising from the drainage areas or on nearby hill slopes, particularly on south aspects, can be expected to be ahead in spring growth compared with pastures experiencing cold air drainage.

Pasture soils are largely acidic, often drought-stressed during the summer when highest temperatures occur. These factors place great stress on perennial pastures, which has partially been offset by irrigation from surface and ground water sources. Pastures situated on steep slopes mixed with flat valley bottoms create a challenge to apply lime for soil pH adjustment, apply nutrients or renovate if needed.

These pastures can also create management challenges because of temperature affected phenology differences between the plants in the valley bottoms and the ones on the hillsides.

More winter hardy species and varieties of grasses are required for pasture and conserved forage production.

MLRA 7: Columbia Basin

Natural features: This MLRA is positioned within south central Washington with a small percentage in north central Oregon. It can be generally described as gently rolling plains with steep basalt ridges and dissected by rivers and streams. The entire MLRA is underlain with basalt flows that are buried with eolian, lacustrine, and alluvial deposits largely created from multiple breaching of ancient Glacial Lake Missoula, the last one about 16,000 years ago. Elevations of the Columbia Basin are between 300 to 1,200 feet (91 – 366 m) but extends up to

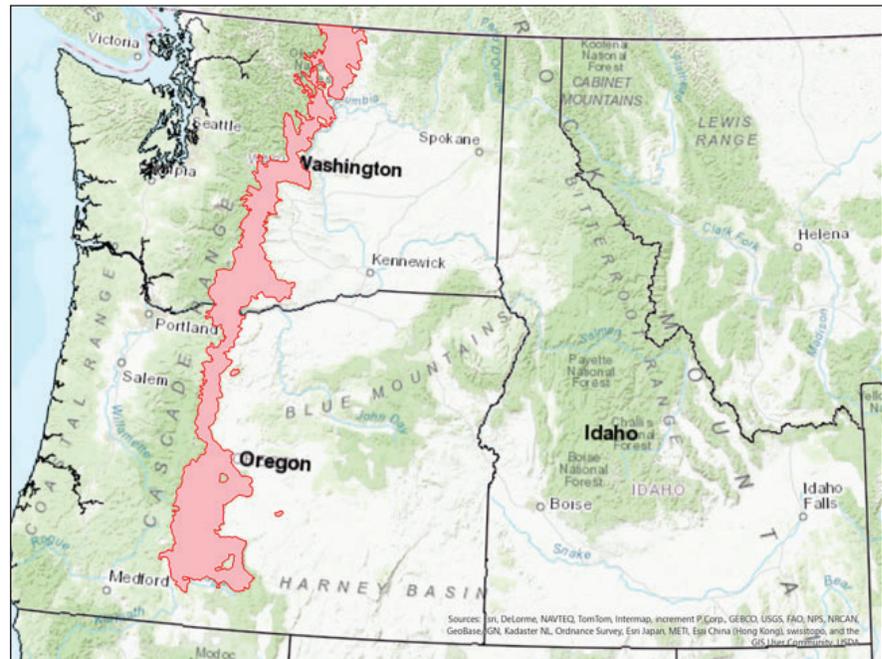


Figure 3 - MLRA 6- Eastern Slopes of the Cascade Mountains



Figure 4 – Classical pastures in MLRA 6.

2,000 feet (610 m). Dominant soil orders include Aridisols and Entisols with mesic soil temperature and aridic soil moisture regimes. The soils are generally moderately deep to very deep and support mixed shrub steppe plant communities with sagebrush, bitterbrush, or greasewood with a variety of grasses or forbs depending on soil texture and depth to water table.

Environmental factors: The combination of lower elevation and rain shadow results in extreme arid growing conditions, but with a long potential growing season. The freeze-free periods average around 160 days but is typically between 130 and 200 days. The average annual precipitation for MLRA 7 is between 6 to 10 inches (152 - 254 mm) primarily from winter rain and snows. Soil and air temperatures suitable for cool season grass growth start in early March and become optimal in April and May. By June, temperatures in this MLRA may still be suitable for growth, however, soils will have dried-out

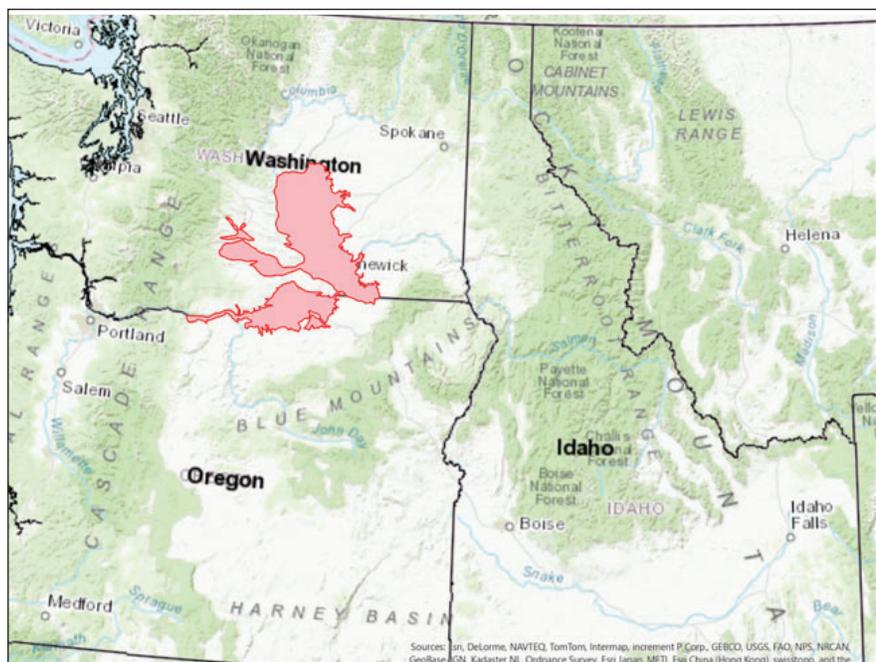


Figure 5 - MLRA 7- Columbia Basin



Figure 6 – Classical irrigated pastures in MLRA 7.

providing insufficient moisture for growth and summers are very dry. With the development of Cascade Mountain reservoirs and Columbia River dams, irrigated cropland, and pasture use about 80% of available surface water.

Soils above the bedrock are interspersed with gravelly silt loams to nearly pure sands. Most soil series are based on calcareous loams and relatively neutral to alkaline. These soils are often well drained, low in OM and water holding capacity. They are highly productive agricultural soils under irrigation.

Challenges: The majority of the 6 to 10 inches (152 – 254 mm) of precipitation falls between mid-October through March. For most of this time, daylength and temperature for plant growth are not favorable although soil water is significantly recharged during this period. Favorable growing temperatures occur March through June. About the time growing conditions are optimal for plants, soils become dry, limiting growth

and production. The active growing season or forage production period for non-irrigated upland pasture in MLRA 7 is March – June. Most non-irrigated uplands are managed as rangelands and produce typically less than 1,000 lbs/ac (1121 kg/ha) annually. Pastures irrigated through the summer, however, can produce up to 10 times that amount within the freeze free period.

Numerous forage species are appropriate for irrigated pasture in this MLRA, but only cool season bunchgrass, introduced or native, are suitable for most dryland situations. Intermediate (*Thinopyrum intermedium*) and pubescent wheatgrass (*Thinopyrum intermedium ssp. barbulatorum*), however, may be appropriate for bottomland pastures. These and other factors create the perfect habitat for cheatgrass (*Bromus tectorium*) and medusahead wildrye (*Taeniatherum caput-medusae*) to invade perennial grasslands in the Columbia Basin. Both are winter annual grasses, invasive, shallow rooted, prone to wildfires and well adapted to this region. They can provide some grazable pasture when most other cool-season perennial species are dormant, then mature and die as temperatures increase and soils dry. The limited rainfall, especially in the warmer months, may never reach the soil surface as it is

often captured in the litter and biomass then evaporated before soil infiltration and continued pasture growth. Unlike perennial grasses, neither cheatgrass or medusahead germinate start growth in the fall, they are very competitive in spring when trying to establish perennial grasses. Proper grazing management is the best way to prevent invasion of these annuals into perennial grass pastures.

MLRA 8: Columbia Plateau

Natural features: The Columbia Plateau occupies the area around and above MLRA 7 Columbia Basin with about 75 % located in Washington. The remaining area is in Oregon with a small portion in Idaho. The plateau is nearly level to steeply sloping rolling hills with incised valleys surround by the Cascade Mountains to the west, Blue Mountains on the south, and the Northern Rockies near the Canadian border. MLRA 8 is greatly influenced

by the rain shadow effect of the Cascade Mountains. Elevation ranges between 1,300 and 3,600 feet (396 – 1,097 m). Like MLRA 7, the plateau was formed largely in part from multiple breaching of ancient Glacial Lake Missoula, the last one about 16,000 years ago which dissected a wide expanse of scablands on the east side of the MLRA. The materials overlaying the basalt flows are mainly loess and volcanic ash unlike the Columbia Basin. The dominant soils in MLRA 8 are Mollisols with a mesic temperature and xeric moisture regime. Soils are moderately deep to very deep and primarily loamy in texture supporting a variety of grass and shrub steppe plant communities.

Environmental factors: Natural precipitation ranges from about 10 to 16 inches (254 – 406 mm) per year with the growing season extending between 130 to 245 days averaging about 190 days. Most of the precipitation occurs between October and April and with cooler temperatures, spring growth occurs 3 to 4 weeks later than in MLRA 7. Land use on the Columbia Plateau is mostly dry cropland with some pasture and hay produced in areas above 14 inches (356 mm) of annual precipitation. Drier sites incorporate summer fallow systems and with areas near surface water irrigated. Approximately 77% of surface water is used for irrigation, taking advantage of longer growing season by extending moisture availability.

Challenges: The majority of the 10 to 16 inches (254 – 406 mm) of precipitation falls between mid-October through April. For most of this time daylength and temperature for plant growth are not favorable although soil water is significantly recharged during this period. Favorable growing temperatures occur April through June. About the time growing conditions are optimal for plants soils become dry, limiting growth and production. In effect, the growing season for non-irrigated upland pasture is April through June. Because of this, most non-irrigated uplands produce significantly less than irrigated lands. Pastures irrigated through the summer may produce up to 10 times annual production. Numerous forage species are appropriate for irrigated pasture but only a limited number of cool season species,

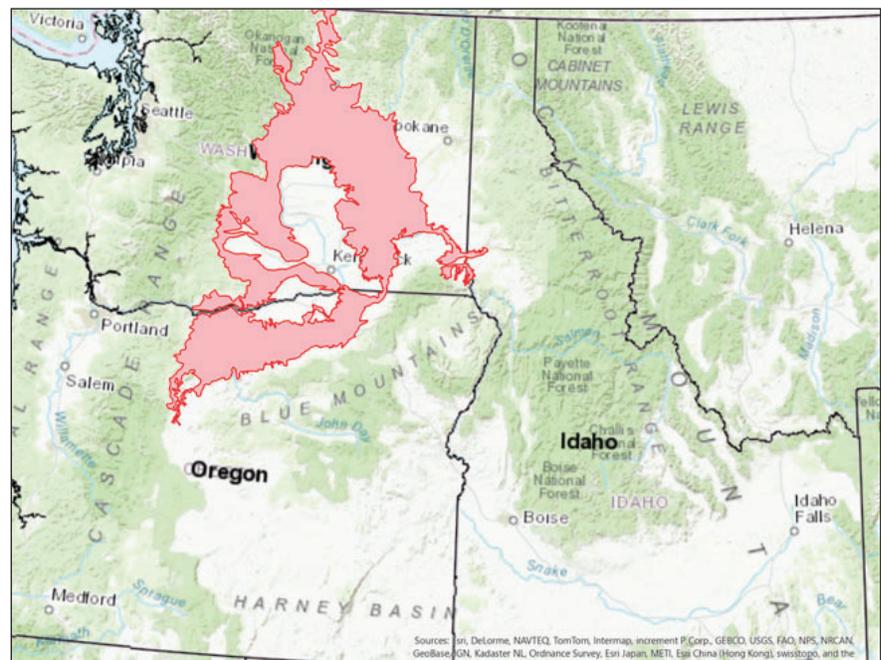


Figure 7 - MLRA 8 - Columbia Plateau



Figure 8 – Classical irrigated pastures in MLRA 8.

introduced or native, are suitable for most dryland situations.

Another challenge these MLRA's offer is the lack of green up by native grasses in the fall. Early to mid-fall is typically a dry time of year in this MLRA so even though temperatures are favorable for growth soil moisture is lacking. Consequently, most years do not have a fall flush of forage that other areas of the country may experience. This needs to be considered when grazing earlier in the growing season because one cannot depend on plant regrowth going into the winter. Introduced bunchgrasses, such as crested wheatgrass, are better at regrowth under these fall conditions so it's more common to see green-up with these grasses.

These and other factors create the perfect habitat for cheatgrass and medusahead wildrye to invade perennial grasslands in the Columbia Plateau. Both are winter annual grasses, invasive, shallow rooted, prone

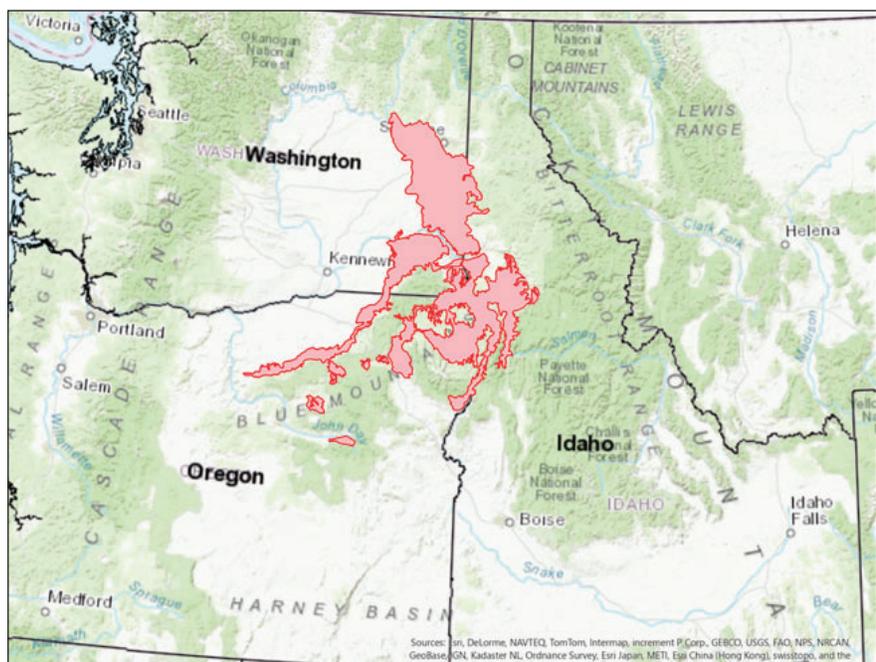


Figure 9 - MLRA 9- Palouse and Nez Perce Prairies



Figure 10 – Classical landscape and pastures in MLRA 9.

to wildfires and well adapted to this region. They can provide some grazable pasture when most other cool-season perennial species are dormant, then mature and die as temperatures increase and soils dry. In precipitation limited areas, rainfall, especially in the warmer months, may never reach the soil surface as it is often captured in the litter and biomass, then evaporated before soil infiltration into the soil for continued pasture growth. Unlike perennial grasses, these invasive annuals do not provide much erosion control. Another management challenge is, since they germinate and start growth in the fall, they are very competitive in spring when trying to establish perennial grasses. Proper grazing management is the best way to prevent invasion of these annuals into perennial grass pastures.

MLRA 9: Palouse and Nez Perce Prairies

Natural features: MLRA 9 intersects at the eastern corners of Washington and Oregon and the west central edge of Idaho, essentially a perimeter wrapping around the

Blue Mountains with ‘fingers-like’ valleys extending west into Oregon and south in Idaho. About half of MLRA 9 is found in Washington with the remaining split about equally between Oregon and Idaho. Combining north and south facing slopes with ridgetops to bottomlands creates a unique, intermediate elevation grassland compared to others in the PNW. Elevation can range from 750 feet (229 m) to about 6,000 feet (1,829 m) but averaging about 2,250 feet (686 m) and slopes from 2 % to greater than 50 % but averaging about 23 %. Basalt or metasedimentary bedrock can range from about three feet and below with soil temperatures mostly frigid but interspersed with mesic. Soil organic matter (SOM) ranges from less than 1 % to greater than 4 % but averages about 2.3 %. Less than 1/3 of MLRA 9 is used a grassland / pasture with greater than 50 % in annual crop production. Because natural precipitation ranges about 13 to 30 inches (330 – 762 mm), dryland grain crops dominate. Less than 55 % of the fresh water is used for irrigation.

Environmental factors: The apparent tremendous physical variability of these Tri-State linked prairies is more uniform where crop

farming and grassland agriculture are the major enterprises. Most of the agriculture crops and pastures are grown on silty soils with series ranging from fine sandy loam to clayey loam soils. Most soils are well drained, higher in SOM than the Basin with soil pH ranging from slightly/moderately acidic to strongly alkaline. Because of the tremendous elevation differences in MLRA 9, the growing season ranges from about 104 to greater than 180 days. Higher natural precipitation than the Basin provides greater acreages of dryland pastures compared to irrigated forages. Historically, parts of the MLRA 9 grasslands were plagued by fire about every half-century or sooner, which has allowed for invasive species and weeds to invade reducing both pasture yields and quality.

Challenges: Although lower elevation than the Blue Mountains that MLRA 9 encompasses, these prairie grasslands soil temperatures are frigid at higher elevations and mesic at intermediate and lower elevations. MLRA 9 is one of the higher grassland elevations in the PNW with a shorter growing season because they are largely isolated

to higher elevations where annual grain crop production is difficult. These grasslands can be productive but special care is needed in fall to not overgraze as grasses need energy for new root development and apical meristem production. Soil moisture becomes limited in mid-summer causing dryland pastures to quickly mature then go dormant until the following spring. Under irrigation, pastures can be established early fall or mid-spring. Long-term nitrogen fertilizer in combination with porous soils has leached some bases, increasing soil acidity issues and costs of forage production. In many grassland areas, maximum pasture growth starts in April but occurs mostly in May and June. Hot summer temperature causes pastures to go dormant in July and August.

Ventenata (Ventenata dubia) is a weedy winter annual that can invade pastures in this MLRA. Similar in growth to cheatgrass and medusahead, it germinates in late fall and then grows vigorously, and competes with perennial grasses, in the spring. Unlike cheatgrass, however, because of its high silica content, *ventenata* has almost no forage value. Proper grazing management is the best way to prevent invasion of this annual into perennial grass pastures.

MLRA 10: Central Rocky and Blue Mountain Foothills

Natural features: MLRA 10 extends from the east slopes of the Cascade Mountains in Oregon about $\frac{3}{4}$ of the distance from west to east into Idaho between the 43rd and 44th latitude. About 71 % of MLRA 10 is from ancient lava flows which created the pumice and Dry Fossil Beds, located in Oregon, while 29 % of 10 resides as a long finger-like projection just north of MLRA 11 from younger volcanic flows in eastern Idaho that came from Yellowstone volcanos. MLRA 10 soils are based on alluvial deposits in the valleys range from pumice east of the Cascade Mountains to loamy sands and clay east bound, due to the massive flooding that carved MLRA 11 from ancient Lake Bonneville. Mollisols soils are dominant and derived from long-term growth of grasslands. In the dry areas, soils are Aridisols. Elevation increases from just over 1,000 feet (305 m) in the west of MLRA 10 to greater



Figure 11 - MLRA 10 - Central Rocky and Blue Mountain Foothills



Figure 12 – Classical rangeland / dryland pastures in MLRA 10.

than 6,000 feet (1,829 m) in eastern Idaho. Soil temperatures decrease with increases in elevation, which would be frigid / cryic to lower elevations where soil temperatures are largely mesic.

Environmental factors: The orientation and linkage of MLRA 10 with MLRA 11 is apparent. Like most of the Inland region of the PNW, MLRA 10 receives precipitation from fall through winter and spring but very dry in the summer. Precipitation ranges from 8 to 16 (203 – 406 mm) inches and up to 41 inches (1,041 mm) at the higher, northern elevations of MLRA 10. About $\frac{2}{3}$ of the fresh water is used for irrigation with about 85 % of the land resource used as pastures and grasslands. Natural plant communities average about 80 - 90% perennial cool-season grasses. At lower elevations and flat slopes, soil temperatures warm quickly allowing for early spring pasture growth. In many grasslands areas pasture growth starts in March with maximum growth in May and June.



Figure 13 - MLRA 11 - Snake River Plains



Figure 14 – Classical irrigated pastures in MLRA 11.

Summers are largely cooler than nearby MLRA's, and snowfall can be heavy in winter. Final killing frost can occur from early September until October. Because of the tremendous elevation differences in MLRA 10, the growing season averages about 140 days but ranges from 60 to greater than 200 days. Higher natural precipitation than the Basin provides greater acreages of dryland pastures compared to irrigated forages. Historically, parts of the MLRA 10 grasslands were plagued by fire about every 20 years or sooner, which has allowed for invasive species and weeds to invade reducing both pasture yields and quality.

Challenges: About 45 % of MLRA 10 is managed by the Bureau of Land Management, slightly less than MLRA 11, at 50 % federally owned. Hillside slopes range from less than 5 % to greater than 65 %. Soils are excellent for growing pastures and forage crops, such as alfalfa (*Medicago sativa*) on flatter landscapes. Spring frosts are

unpredictable in that a frost event can occur when grass hay crops are in Growth Periods 5b, 6a or as late as 6b when grass growth is jointing / heading. These freezing events can cause small grains heads to turn white and not fill or kill the growing point of perennial grass tillers as they extend upward. This will stunt the perennial grass and regrowth will be delayed a month or more. The long growing season allows for multiple grazing / hay crop cuttings when adequate irrigation water is available. Soil pH is acidic (5.9 – 6.9) to normal with few soils where pH is > 8. Overgrazing increases dominance of cheatgrass in some areas and Kentucky bluegrass (*Poa pratensis*) in others. These grasslands can be productive but special care is needed in fall to not overgraze as grasses need energy for new root development and apical meristem production. Soil moisture becomes limited in mid-summer causing dryland pastures to quickly mature (Period 9) then go dormant (Period 10) until the following spring. Under irrigation, pastures can be established early fall (Period 2a) or mid-spring (Periods 5a/5b) (Introduction Chapter 7). Long-term nitrogen fertilizer in combination with areas of porous soils has leached some bases increasing soil acidity issues and costs of forage production.

MLRA 11: Snake River Plains

Natural features: About 94 % of MLRA 11 stretches across southern Idaho with 6 % into eastern Oregon. This MLRA was carved by ancient Lake Bonneville, which covered much of northern Utah but was dammed by alluvial materials near Red Rock Pass, Idaho. With one major breach, about 15,000 years ago, of this natural dam Lake Bonneville dropped more than 350 feet (107 m) with 1,000 ft³ miles (4,168.2 km³) of water washed the Snake River Canyon eventually discharging in the Columbia River near Pasco, Washington. This single flooding event changed the landscape of the region leaving steep canyons in areas but also flat plains and bottomlands. With the Rocky Mountains adjacent to the east, elevation of the Snake River Plains ranges from 2,100 to 5,000 feet (640 – 1,524 m). Basalt or metasedimentary bedrock can range from about three feet (0.9 m) and below with soil

temperatures mostly mesic or frigid. Less than 1/3 of MLRA 11 is used as grassland / pasture with greater than 50 % in crop production. Because natural precipitation ranges between 7 to 12 inches (178 – 305 mm), rangeland and irrigated crops dominate the landscape. Approximately 62 % of surface water is used for irrigation.

Environmental factors: Rangeland and irrigated cropland are the most common land uses of this MLRA due to low natural precipitation. Annual precipitation occurs primarily as rain in the spring and fall with a mix of rain and snow during the winter. The amounts range from 7 to 12 inches (17.8 – 305 mm) but can reach up to 20 inches (508 mm) in the upper reaches of the Snake River drainage. Average temperatures for the region range from 41° to 55° F (5° to 12.8° C) with freeze-free periods ranging from 110 to 220 days. Soils throughout MLRA 11 are Aridisols with mesic to frigid soil temperature regimes and arid moisture regimes. Soils are primarily finer textured and moderately deep with good drainage.

Challenges: Limited soil moisture, invasive species and frequent fire return intervals impact management strategies and forage availability in this MLRA. Approximately 50 % of the Snake River Basin is publicly owned and managed as low productive rangelands. Invasive species such as cheatgrass and medusahead have increased fire return intervals and compete with native sagebrush steppe species such as big sagebrush (*Artemisia tridentata*) and bluebunch wheatgrass (*Pseudoroegneria spicata*). Irrigated lands are used for a variety of crops including potatoes (*Solanum tuberosum*), sugar beets (*Beta vulgaris*), corn (*Zea mays*), alfalfa, and pasture. These croplands can be susceptible to wind and water erosion, nutrient loss, and reduced water quality. Reduced tillage, crop rotation, irrigation water management, nutrient management, pest management, and prescribed grazing can be used to address concerns in these systems.

MLRA 12: Lost River Valleys and Mountains

Natural features: The area is intersected with steep mountains and deep valley bottoms in East central Idaho. It is nearly 85 % publicly owned and is primarily



Figure 15 - MLRA 12- Lost River Valley and Mountains



Figure 16 – Classical dryland pastures found in MLRA 12.

used as rangeland. Elevations range from 4,000 to >12,000 feet. Although approximately half of the MLRA consists of steep mountainous slopes the valleys are broad and level providing opportunities for crop and forage production. Precipitation ranges from 7 to 45 + inches (178 – 1,143 mm) and occurs as rain and snow in spring fall and winter. Irrigated lands are a major water use for this area with approximately 63 % surface water used for irrigation.

Environmental factors: The MLRA can be characterized as primarily rangeland with production values from low to moderate in the lower valleys and slopes. Plant communities range from shadscale (*Atriplex confertifolia*)/Indian ricegrass on valley floor to mountain big sagebrush/ Idaho fescue (*Festuca idahoensis*) sites on lower slopes. The average annual precipitation occurs throughout the fall, winter, and spring ranging between 7 and 25 inches

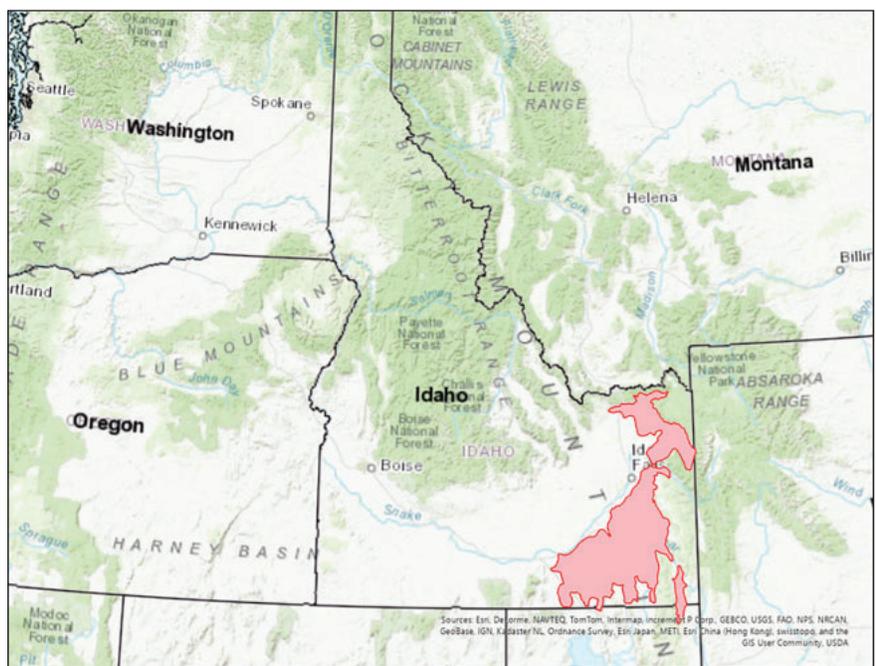


Figure 17 - MLRA 13- Eastern Idaho Plateau



Figure 18 – Classical rangeland / dryland pastures in MLRA 13.

(178 – 635 mm) on the lower foothills and valleys. The average temperatures are between 35° and 45° F (1.7° – 7.2° C) and the freeze-free period averages around 110 days with a range of 65 to 150. Soils are dominantly Mollisols and Aridisols with soil temperature regimes as frigid or cryic and moisture regimes as xeric or aridic. Soils are primarily deep with loamy or sandy textures with good drainage, and many are skeletal.

Challenges: Limited soil moisture and steep slopes limit production capacity in this MLRA. Irrigated pasture and hay depend on available surface water which is dependent on winter snowpack in the mountains. Wind and water erosion are concerns in this MLRA leading to loss in productivity. Improper irrigation may lead to excessive soil loss and damage to streambanks which may impact water quality and fisheries. Reduced tillage, crop rotation, irrigation water management, nutrient management, and prescribed grazing can be used to address concerns in these systems.

MLRA 13: Eastern Idaho Plateau

Natural features: MLRA 13 is the valleys and foothills in eastern Idaho. It is predominantly west facing alluvial slopes with ridgetops to bottomlands creating intermediate to high elevation grassland that are approximately 75 % private lands. Land uses for this MLRA are primarily cropland and rangeland. Rangelands are predominately sage steppe and grassland communities composed of big sagebrush, bitterbrush (*Purshia tridentata*), and several perennial bunchgrasses. Dry cropland producing wheat and barley is common on the upper slopes and foothills while lower elevation cropland is irrigated, producing a variety of crops. Approximately 66 % of surface water is used for irrigation. Elevation ranges from 4,500 feet (1,372 m) to about 6,600 feet (2,012 m). Precipitation comes in the form of rain and snow through fall winter and spring with an occasional thunderstorm during the summer months.

Environmental factors: Grazing land and cropland are the primary uses in this MLRA. Rangeland have moderate to high production values when compared to adjacent land areas and are comprised of sagebrush grasslands. Dominate species include mountain big sagebrush, bluebunch

wheatgrass and Idaho fescue. Dry cropland consisting of wheat and barley are common in higher elevations of the MLRA while irrigated cropland follows the edges of the valley along MLRA 11. Precipitation ranges from 12 to 25 inches (305 – 635 mm) through much of the area although increases upslope. The freeze-free period ranges from 90 to 175 days with an average of about 130 days. The soils in the area are dominantly Mollisols and have a frigid or cryic soil temperature regime, a xeric soil moisture regime. Soils generally are deep or very deep, well drained, and loamy in texture.

Challenges: Croplands in this MLRA are susceptible to wind and water erosion when soils are exposed. Upslope winds in the fall and spring as well as spring snowmelt can have significant impacts on the amount of erosion each year. Implementing practices such as conservation cover, cover crops, irrigation water management, crop rotations, and grazing management can address some of these concerns.

MLRA 21: Klamath and Shasta Valley Basins

Natural features: MLRA 21 is evenly spread between Oregon and California. Elevation generally ranges from 2,400 to 7,000 feet (732 – 2,134 m) on higher ridges. However, Mt. Shasta is the highest peak in the area at 14,440 feet (4401 m). Most of the space being used for agriculture in MLRA 21 is in valleys, which are enclosed by mountain ridges that range from 3 to 25 miles (5 – 40 km) in length. Major water reservoirs include Agency Lake, Upper Klamath Lake, Gerber Reservoir, Drews Reservoir, Clear Lake, and Goose Lake. Agency and Upper Klamath Lake covers around 60,000 acres (26,709 ha) with an average depth of 12 feet (3.6 m). The northern part of Upper Klamath Lake drains into the Williamson, Sprague, and Wood Rivers, which are used for irrigation purposes in Sprague River and Wood River Valleys. The southern end of Upper Klamath Lake feeds into the Klamath River, which runs into Copco Lake just beyond the California border. Upper Klamath Lake is the major irrigation water reservoir that delivers water to the Klamath Irrigation Project that includes Klamath Falls, Poe Valley, Yonna Valley, and Langell Valley. The Lost River, which originates in California, comes up to Oregon, and back down to California again, also delivers water to the Klamath Irrigation Project.

Environmental factors: Annual precipitation in MLRA 21 ranges from 10 to 35 inches (254 – 889 mm), with an average of 10 to 15 inches (254 – 381 mm) in the valleys in the Klamath Basin, an average of 14 to 17 inches (356 – 432 mm) in the Shasta basin, and an average of 30 to 40 inches (762 – 1,016 mm) towards the west side of this MLRA at the lower levels of the Cascades. Around 44 % of the precipitation occurs during the winter, 22 % in the spring, 8 % in the summer, and 26 % in the fall. The bulk of precipitation in this MLRA generally occurs October through March, and summers are very dry. Average annual snowfall in the Klamath Basin lies between 15 to 45 inches (381 – 1,143 mm) but may accumulate as much as 2 to 3 feet (61 – 91 cm). Snow typically falls in the



Figure 19 - MLRA 21- Klamath and Shasta Valley Basins



Figure 20 – Classical irrigated pastures in MLRA 21.

Shasta Basin every year, but usually does not remain on the ground for very long.

Temperatures throughout the high precipitation season of October through March will generally range between 0° and 40° F (-17.8° – 4.4° C) and ranges between 40° to 95° F (4.4° – 35° C) during the growing season, on average. However, temperatures can reach 100°F some days, and there is potential for a frost to occur every month of the year. The southernmost 75 % of the MLRA has a growing season of 90-120 days. The northernmost 25 % of this MLRA has a much shorter growing season of 50 - 70 days, perhaps more suitable for pasture, rye (*Secale cereale*), or oat hay (*Avena sativa*) rather than irrigated crops like potatoes, wheat and barley.

This MLRA has an extremely wide variety of soils. Perhaps due to, in-part, the eruption of Mt. Mazama (which is how Crater Lake was formed), which covered



Figure 21 - MLRA 23 - Malheur High Plateau



Figure 22 – Classical irrigated pastures in MLRA 23.

the northernmost area of this MLRA with a thick layer of pumiceous ash almost 7,000 years ago. Soils affected by the pumiceous ash don't hold heat very well which causes a high degree of variation in soil temperature, which significantly increases the potential of night-time frosts. Soils that are found in the valleys of the Klamath Basin are, again, very diverse, typically consisting of a combination of loam, silt, and sand. These soils are not very deep and lie upon a very rocky and gravelly soil profile. The major contributor to this soil has been years and years of leftover organic residue from harvested crops and animal excrement. Soils in the Shasta Basin have a reputation for being rather sandy.

Challenges: The biggest challenge to growing and managing pasture forages in the Klamath Basin concerns both quantity and quality of irrigation water. Historic allocations average about 3.5-acre feet (4,317,186 L) of irrigation per acre of land. Indigenous populations of endangered suckers in Upper Klamath Lake and threatened Coho Salmon in the Klamath River have altered

irrigation deliveries to project users since the mid-1990's. Irrigation allocations are highly dependent on winter snowpack levels and definitive volumes for irrigation are often not determined prior to the April 15th start date. Producers therefore deal with a high level of uncertainty, in terms of future irrigation water availability.

Irrigation water quality is also a concern, as excessive nitrogen, and phosphorus levels in the Upper Klamath Lake cause algae blooms during the growing season. These blooms make the irrigation water smell awful and clogs up irrigation systems. Lastly, it should be mentioned that a frost may occur at any time during the year.

MLRA 23: Malheur High Plateau

Natural features: Approximately 67 % of MLRA 23 is in Oregon. All of this MLRA is on the Intermontane Plateaus. Elevation ranges from 3,900 to 6,900 feet (1,189 – 2,103 m) in most of the area, but it exceeds 9,000 feet (2,748 m) on some mountains. This area consists primarily of nearly level to moderately steep plateaus, basins, and valleys bordered by long, gently sloping alluvial fans. Occasional north-south trending fault-block mountain

ranges separate the basins. Volcanic plateaus rise sharply above the valleys. The area has no major rivers. It consists mostly of closed basins.

Most of this area consists of young andesite and basalt layers. Older volcanic rocks and marine and continental sediments are exposed in the mountain ranges. These north-south trending ranges are uplifted fault blocks. The basins between the mountains and lava plateaus are filled with a mixture of Quaternary alluvium, continental sediments, and volcanic ash. The long alluvial fans consist of coarser alluvium near the mountains and fine-grained sediments at their distal ends. Playas or shallow lakes are common in the lowest areas within the closed basins.

Environmental factors: In most of this area, the average annual precipitation is 6 to 12 inches (152 – 305 mm). It is as much as 57 inches (1,448 mm), however, in the mountain ranges. The precipitation is evenly distributed throughout fall, winter, and spring, but is low in summer. Snow can occur throughout the area in winter. The average annual temperature is 39° to 52° F

(3.9° – 11.1° C), decreasing with elevation. The freeze-free period averages 105 days and ranges from 35 to 175 days, decreasing in length with elevation.

About 98 % of the freshwater is used for irrigation with the 88 % from surface water sources originating from melting snow or higher elevation rainfall. Streamflow is erratic and depends mostly on runoff from melting snow. Most of the water is used for irrigating grain and hay for cattle feed. Irrigated areas are on alluvial fans and pluvial lake terraces. Surface water from mountain runoff is generally of excellent quality. As the water seeps through the alluvial fan deposits, salts left in the soil, as a result, of evapotranspiration are dissolved. In the wetter years, when springs discharge this seepage water at the toe of the fan, the water quality is degraded. As the surface water evaporates on its path to a playa, the salt concentrations increase, making the water unsuitable for all uses. The large supply of ground water in the gravel- and sand filled valleys and basins is mostly untapped. The basin fill deposits in Oregon have soft to moderately hard water with a median concentration of about 170 parts per million total dissolved solids. The ground water near the alluvial fans typically has lower levels of total dissolved solids than the ground water near playas. Wells closer to the playas typically contain 1,000 or more parts per million (milligrams per liter) total dissolved solids. The volcanic rocks are aquifers; but they are little used, and not much is known about the range of water quality. Water can be found in layers of rubble, cracks, and tubes within the lava. Layers of alluvium and continental sediments occurring between the andesite and basalt flows also may contain ground water.

The dominant soil orders in this MLRA are Aridisols and Mollisols. The soils in the area dominantly have a mesic or frigid soil temperature regime, an aridic or xeric soil moisture regime, and mixed or smectitic mineralogy. The soils on uplands generally are well drained, loamy or clayey, and shallow or moderately deep. The soils in basins generally are poorly drained to well drained, loamy or clayey, and very deep. Locally, large areas have an ashy particle-size class and glassy mineralogy.

Challenges: This area supports a shrub-grass association. Big sagebrush, low sagebrush (*Artemisia arbuscula*), rabbitbrush (*Ericameria nauseosa*), needlegrasses, and squirreltail (*Elymus elymoides*) are common on the plateaus and mountains. Big sagebrush and basin wildrye (*Leymus cinereus*) are on bottomlands. Spiny hopsage (*Grayia spinosa*) and bud sagebrush (*Picrothammus desertorum*) are on the drier sites. Greasewood (*Sarcobatus vermiculatus*), saltbush (*Atriplex canescens*), and saltgrass (*Distichlis spicata*) grow on salty and sodic soils in basins. Silver sagebrush (*Artemisia cana*) grows on moist sites that have intermittent water, such as areas along the margin of playas.

About 84 % of the land within MLRA 23 is pasture and grasslands with about 2/3 owned by the Federal government. Native range vegetation covers much of the area. Livestock production on rangeland is the principal agricultural enterprise. A small percentage of the area is used for irrigated alfalfa hay, grain, hay for winter feed, or pasture. Pasture and hay provide seasonal feed for livestock. Small areas on the upper mountain slopes are forested.

The major soil resource concerns are control of wind erosion and reduction of the content of salts and sodium in the areas of soils used for production of crops or hay. Conservation practices on cropland generally include irrigation water management, crop residue management, and toxic salt reduction. Prescribed grazing, brush management, and development of watering facilities are important conservation practices on rangeland. How much precipitation and when it comes from year to year always affects grass growth on range and dryland pastures. In drier years, fire on the range has become more of a concern with its effect on ranching operations. Closer attention must be paid to species of grasses and legumes to plant because of salt and saline soils. Forage species selected need to be drought tolerant because of the risk of running out of surface irrigation water in the summer. Salt accumulation in the soil must be managed as well.

Figure 23 - MLRA 24- Humboldt Area

Natural features: A very small portion of this MLRA extends into Southeast Oregon, with the majority of this MLRA existing in Northwest Nevada. Some noteworthy natural features in this area include Calico Mountains, Pine Forest Range, Black Rock Range, Jackson Mountains, and the Bill Creek Mountains. Major valleys include Black Rock Desert, Desert Valley, and Continental Lake Valley. Elevation in this MLRA ranges from 3,900 feet to 9,458 feet (1,189 – 2,883 m). Agriculture mainly takes place on the valley floors, which experiences intermittent and short-lived floods. Rivers that drain the Trout Creek Mountain and Santa Rosa Range watersheds intermittently run through these valleys. The depth needed to drill into the earth to create a well is very deep, and the quality of well irrigation water is usually quite poor due to its dissolved salt content. Surface water and springs that run from higher elevations are very important sources of irrigation water for this area.

Environmental Factors: Temperatures in this MLRA are generally warm in the summer and cold in the winter. The lowest recorded temperature in Humboldt County in -25 °F (-31.7 C), although the average temperature during the winter is around 32 °F (-1.7 C), and average minimum temperature falling to around 22 °F (-5.6 C). The highest recorded temperature in Humboldt County is 107 °F (41.7 C), with an average summer temperature of 70°F



Figure 23 - MLRA 24 - Humboldt Area



Figure 24 – Classical irrigated pastures in MLRA 24.

(21.1 C), and an average daily maximum temperature of around 88 °F (31.1 C).

Average annual precipitation is around 9 inches (229 mm), with around 30 % of this precipitation falling between May and September, which represents the typical growing season for this area. Average winter snowfall is around 22.5 inches (57.2 cm), with most of this snow accumulating at higher elevations. Much of this snowmelt is used for irrigation in adjoining valleys. Average relative humidity in the afternoon during the growing season is around 33 %, and this humidity typically will double overnight.

Typical vegetation for this area includes Indian Ricegrass (*Achnatherum hymenoides*), Big Basin Sagebrush (*Artemisia tridentata*), and Basin Wildrye. With various types of eroded rock being the main contributor to the soil in this area, soils consist of mostly sand and silt, with some silty clay and sandy loam type soils found intermittently.

Challenges: Erratic water supply and a rather low average annual precipitation in this MLRA makes for a large issue for agriculture to overcome. In addition, the salty and sandy type soils found in this area are of high drainage and low water retention. On top of that, low levels of humidity during the day may significantly increase water demands of crops and forages. Ground water is of low quality and difficult to access. Very sophisticated water management strategies will have to be a priority in order to find success in conducting agricultural activities in this area.

MLRA 25: Owyhee High Plateau

Natural features: This area is composed primarily in southern Idaho (29 %) and Oregon (16 %). The Sawtooth National Forest and numerous wilderness study areas also occur in this MLRA. Most of the wilderness study areas are in the high desert canyon lands of southwestern Idaho.

Environmental factors: This area lies within the Intermontane Plateaus. The northern half of the area lies within the Columbia Plateaus Province and the slope is to the North. This part of the MLRA forms the southern boundary of the extensive Columbia Plateau basalt flows.

Most of the northern half is in the Payette Section, but the northeast corner is in the Snake River Plain Section. Deep, narrow canyons draining into the Snake River have been incised into this broad basalt plain. Elevation ranges from 3,000 to 7,550 feet (915 - 2,300 m) on rolling plateaus and in gently sloping basins. It is more than 9,840 feet (3,000 m) on some steep mountains. The extent of the major Hydrologic Unit Areas that make up this MLRA is as follows: Middle Snake, and 49 % Upper Snake. Reaches of the Owyhee, Bruneau, Salmon Falls Creek, and Rock Creek are the major rivers in this area. The dominant rock types in the area are volcanic and include andesite, basalt, and rhyolite. In the north and west parts of the area, Miocene volcanic rocks dominate, and Cretaceous granitic rocks occur in the mountains. A Mesozoic igneous and metamorphic rock complex dominates the south and east parts of the area. Upper and Lower Paleozoic sediments, including extensive limestone deposits, occur in the mountains. Only a few narrow valleys occur in this area (2 - 3 % of the land area).

Alluvial fan and basin fill sediments occur in the valleys.

The average annual precipitation in most of this area is 7 to 16 inches (178 – 406 mm), but it can exceed 50 inches (1,270 mm) per year in the mountains. The amount of precipitation is lowest in the eastern part of the area and increases with elevation. Rainfall occurs in spring and sporadically in summer. Precipitation occurs mainly as snow in winter. The precipitation is distributed evenly throughout fall, winter, and spring, but is lowest from midsummer to early autumn. The average annual temperature is 35° to 53° F (1.7° - 11° C). The freeze-free period averages 130 days and ranges from 65 to 190 days, decreasing in length with elevation. It is typically less than 70 days in the mountains.

About 47 % of water is from ground water sources, and 53 % is from surface water sources. The supply of water from precipitation and streamflow is small and unreliable, except along the Owyhee, Bruneau, and Salmon Falls Creek Rivers. Streamflow depends largely on accumulated snow in the mountains. Surface water from mountain runoff is generally of excellent quality and is suitable for all uses. Precipitation is adequate for dry farming in a few areas of deep soils in Idaho. The basin fill sediments in the narrow alluvial valleys between the mountain ranges provide some ground water for irrigation. The alluvial deposits along the large streams have the most ground water. Springs are common along the edges of the limestone outcrops.

The dominant soil orders in this MLRA are Aridisols and Mollisols. The soils in the area dominantly have a mesic or frigid soil temperature regime, an aridic or xeric soil moisture regime, and mixed or smectitic mineralogy. They generally are well drained, clayey or loamy, and shallow or moderately deep. Haplodurids formed in loess over alluvium on fan piedmonts and plateaus. Argidurids and some Durixerolls formed in mixed loess and volcanic ash over alluvium on fan piedmonts and plateaus. Other Durixerolls formed in alluvium on alluvial fans and fan piedmonts. Argidurids formed in alluvium on fan piedmonts and stream terraces. Haplargids formed in residuum and colluvium on hills, mountain slopes, and plateaus and in alluvium on alluvial fans, ballenas, and



Figure 25 - MLRA 25- Owyhee High Plateau



Figure 26 – Classical landscape of rangeland and dryland pastures in MLRA 25.

plateaus. Some Argixerolls formed in residuum, alluvium, and colluvium on hills, plateaus, and mountain slopes.

This area supports shrub-grass vegetation characterized by big sagebrush. Low sagebrush and Lahontan sagebrush (*Artemisia arbuscula ssp. longicaulis*) occur on some soils. Antelope bitterbrush, squirreltail, desert needlegrass (*Achnatherum speciosum*), Thurber needlegrass (*Achnatherum thurberiaum*), and Indian ricegrass (*Achnatherum hymenoides*) are important associated plants. Green ephedra (*Ephedra viridis*), Sandberg bluegrass (*Poa secunda*), and several forb species also are common. Juniper-pinyon woodland is typical on mountain slopes and has increased in the valleys because of fire suppression. Jeffrey pine (*Pinus jeffreyi*), lodgepole pine (*Pinus contorta*), white fir (*Abies concolor*), and manzanita (*Arctostaphylos patula*) grow on the highest mountain slopes. Shadscale is the typical plant in the drier parts of the area. Sedges, rushes, and moisture-loving grasses grow on the wettest parts of the wet flood plains and terraces. Basin wildrye, alkali sacaton (*Sporobolus airoides*), saltgrass

(*Distichlis spicata*), buffaloberry (*Sheperdia argentea*), black greasewood, and rubber rabbitbrush grow on the drier sites that have a high concentration of salts.

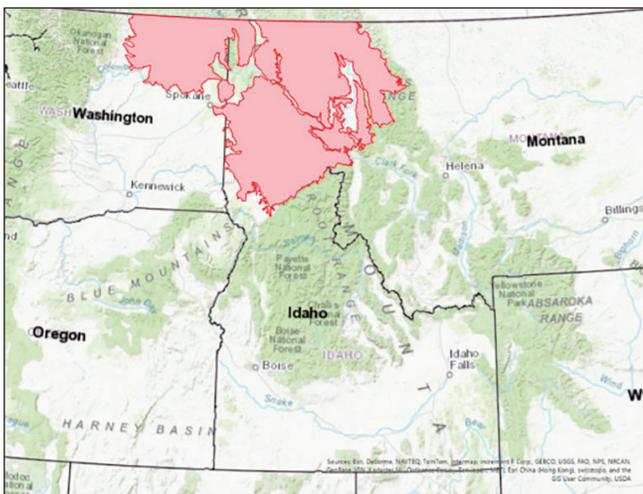
About two-thirds of this area is federally owned. The rest is used mainly for farming and ranching. Grazing of livestock on native grasses and shrubs is the principal agricultural enterprise. About 2 % of the total area, principally in valleys along the major streams, is used for irrigated hay, grain, tame pasture, onions (*Allium cepa*), and potatoes. Private grassland is 23 % and federal grassland is 58 % of the area.

Challenges: The major soil resource concerns are maintenance of the content of organic matter and productivity of the soils and the accelerated erosion resulting from recreational activities. In some areas the content of salts and sodium in the soils is a concern. Forest and rangeland health are additional management concerns. Conservation practices on cropland generally include

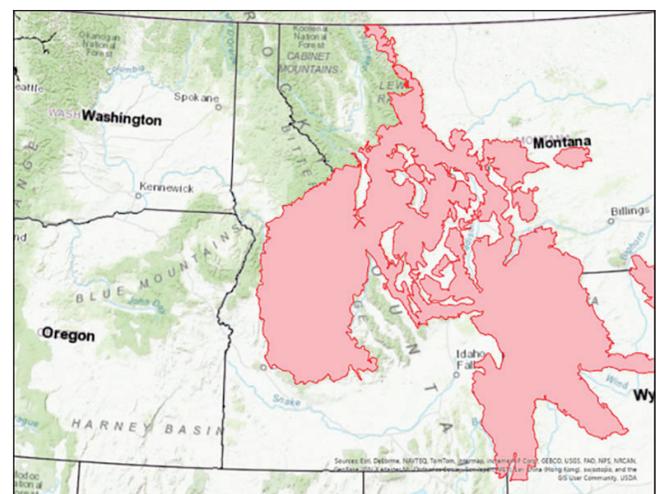
irrigation water management and crop residue management. Prescribed grazing, brush management, and watering facilities are important on rangeland. Pasture and hay provide seasonal feed for livestock. Targeted grazing and green stripping for firebreaks can help to reduce the effects of catastrophic wildfires and the damage caused by invasive plants.

MLRA 43-44: Blue, Rocky and Seven Devils Mountains and Valleys

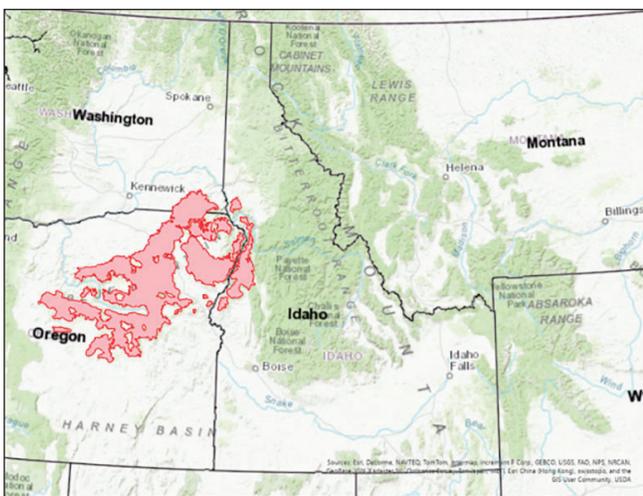
Natural features: We have combined two MLRA's, 43 and 44 because they share many similar physical features in the three PNW states. Forestry is the primary industry followed by forage and livestock grazing. Collectively these combined MLRA's represent more land mass than any other in the region but because of the high elevations, most areas are forested. Grassland is found in nearly flat valleys, which may suffer from spring flooding,



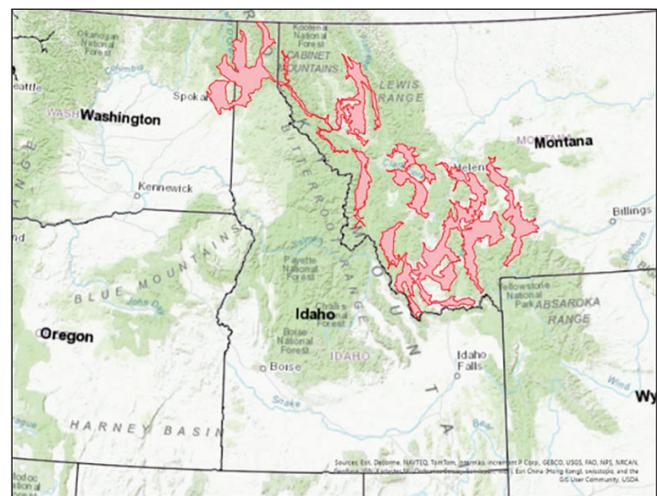
MLRA 43A – Northern Rocky Mountains



MLRA 43B – Central Rocky Mountains



MLRA 43C – Blue and Seven Devils Mountains



MLRA 44 – Northern Rocky Mountain Valleys



Figure 27 – Classical valley floor rangeland and dryland pastures in MLRA 43-44.

surrounded by steep mountain slopes. Valley elevations range from less than 2,000 feet (610 m) to greater than 7,000 feet (2,134 m). The bulk of 43A and 43B is found in Idaho while 43C is largely found in Oregon. Of these MLRA's in Washington, the majority is 43A with a small concentration of 43B and 44 with the major of 44 located in Montana followed by components of 44 in northern Idaho and a small amount in NE Washington. Mollisols and Andisols dominate soil orders with soil temperatures mesic at lower elevations and frigid at higher elevations. Volcanic ash is found in the Blue and Seven Devils Mountain soils. Soil organic matter is often higher in these higher elevation valleys than other MLRA's where growing seasons are longer. It is common that soil organic matter will exceed 15%. Water erosion is always a concern in these valleys. Soils range from gravely to sandy loam to clayey resulting in pH from very acidic (4.5) to alkaline (8.5).

Environmental factors: These high elevation valleys are common in all three PNW states. Elevation of surrounding mountain ranges is very high, with short growing seasons, which also cause rain shadow effects with very dry summers, except for an occasional thunderstorm. Snow is the major source of precipitation, which melts and provides irrigation water during the growing season. On average, greater than 75 % of surface water can be used for irrigation. Frosts can occur any month of the year in higher elevation valleys while a frost-free period of about 105 to 120 days is expected in the lower valleys. Spring flooding occurs nearly every year in some valleys while others seldom flood. Elevation differences dictate when pastures green up in the spring and then transition into dormancy in late fall / winter. Unlike most MLRA's in the PNW, these higher elevation pastures seldom transition into summer dormancy but continue growing based on higher soil organic matter and ground water tables to supply essential crop moisture during the growing season.

Challenges: Perennial grasslands and hay crops are best suited to these high elevation valleys. Valley elevations dictate length of growing season, soil temperature and potential pasture production. At lower valley elevations, mesic soil temperatures allow for rapid dryland pasture and forage growth in the early season however summer drought will shorten the extended potential

growth period for within this region without supplemental irrigation. Some valley bottom pastures may experience cold air drainage from higher elevations which can slow growth. Nighttime and early morning temperatures in these drainages can be several degrees colder than the surrounding area. Pastures up, out of the drainage and/or on nearby hill slopes, particularly south aspects, can be expected to be ahead in spring growth compared with pastures experiencing cold air drainage. At higher valley elevations, summer soils are cool with cold winters, resulting in

very short frost-free periods in summer but water tables are often within three feet (91 cm) of soil surface so deep-rooted forages can reach into the ground water table. The inherent short growing season results in comparatively lower total forage yield, but production can be high during the active growing season within few grazing or hay harvest events. Selecting winter hardy forage species then maintaining soil fertility ensures long term and sustainable pastures and hay fields. High organic matter soils are beneficial to retain moisture during dry summer months and likely reflect excellent forage and pasture production and below ground root mass accumulation during summer months. Soils maybe acidic in some valleys thus liming will help pasture and forage production within these short growing season regions.

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Introduction Chapter 5

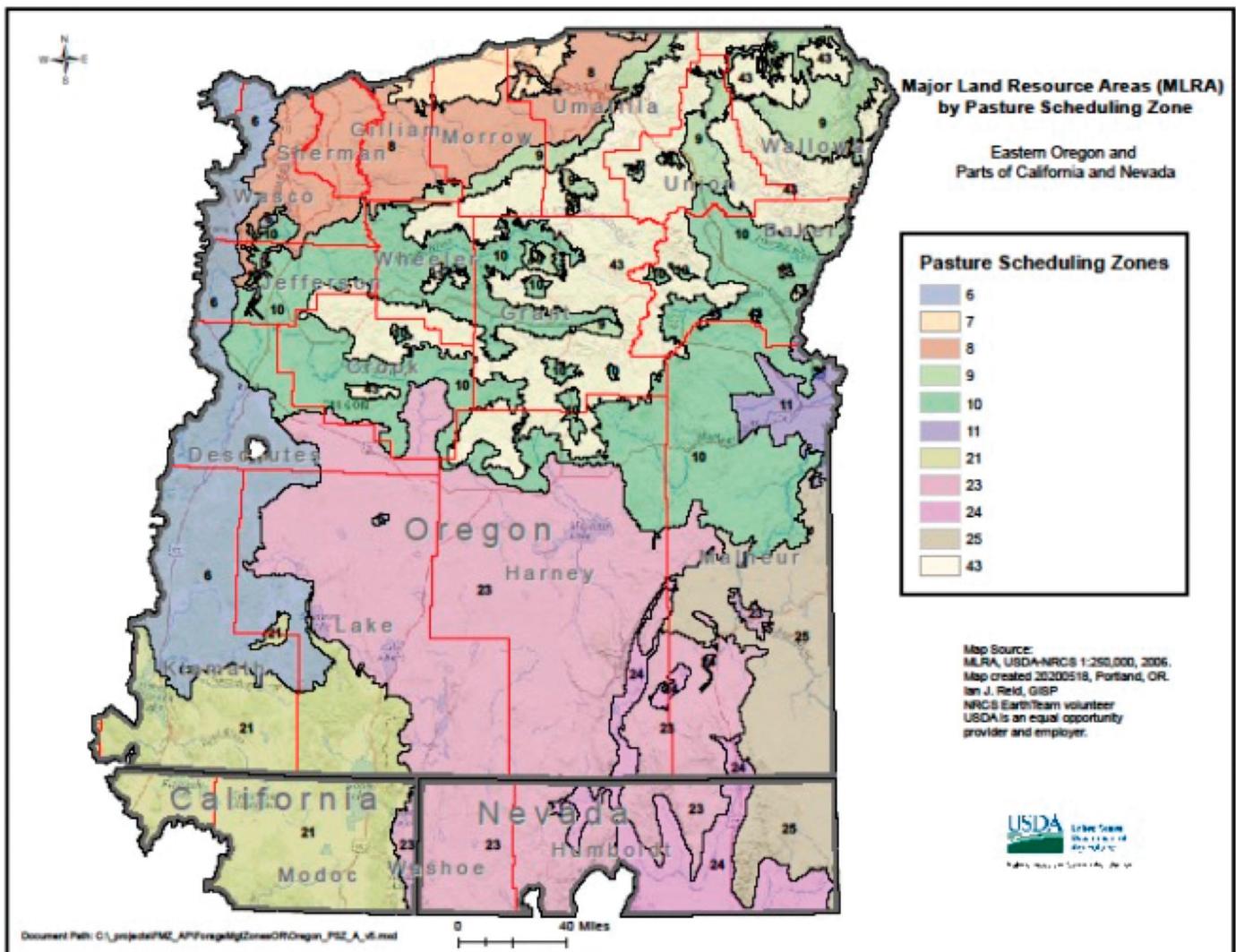


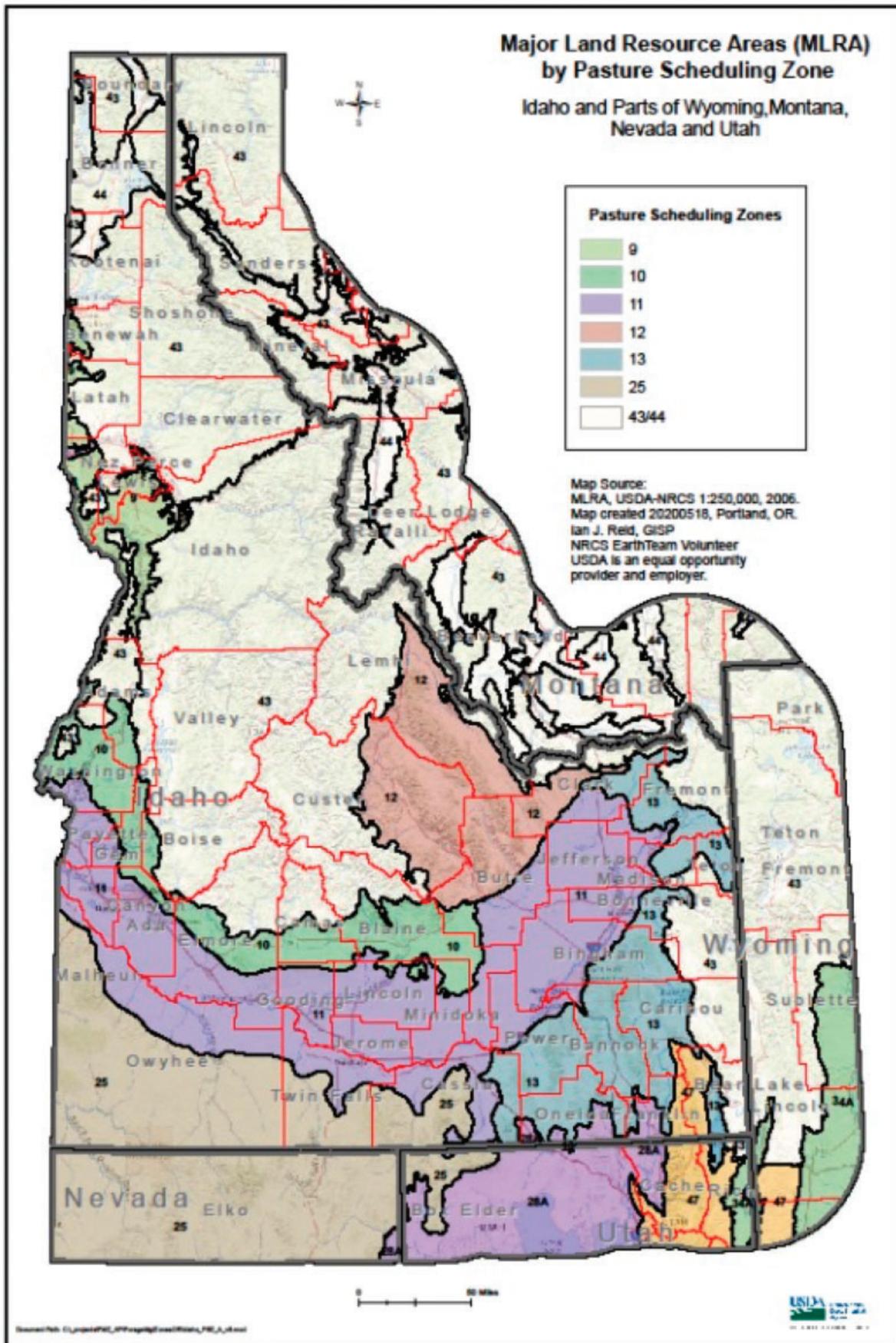
Tri-State MLRA Maps

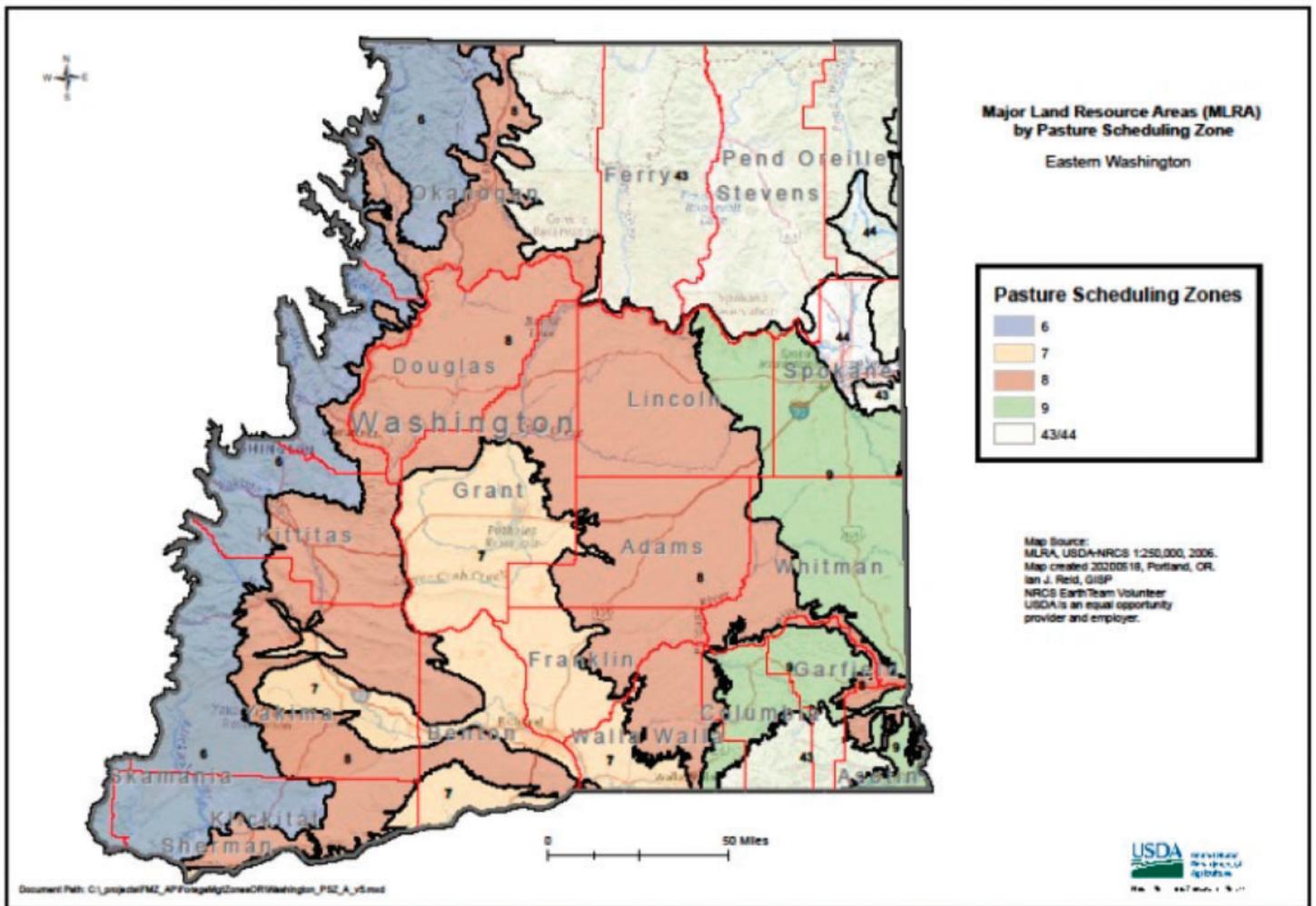
This chapter provides the three PNW state maps differentiating the appropriate Major Land Resource Area (MLRA) within each state. The project team greatly thanks, Ian Reid, retired USDA-NRCS, who prepared these coordinated colored maps. These maps provide the similarities among the three states for the MLRAs, within that state. Many producers within the Inland region are unaware how closely pasture growth and development aligns with producers in a neighboring state in the PNW. We recognize there will be many micro-environment differences

within any MLRA, but within the vary restrictive MLRA components described in Introduction Chapter 4, tremendous similarities exist.

These similarities and differences could be used to provide greater understanding and potential collaboration within producers who may suffer drought, etc. in one MLRA but not in another. Conserved hay can be easily shipped between locations as needs arise, helping all to overcome unknown risks that seem to arise when least expected.









Introduction Chapter 6

Description of Pasture Growth Periods

Throughout the Calendar, reference is made to pasture Growth Periods and pasture grass growth. The following table provides a snapshot that is used throughout the Calendar.

Table 1. Description of Inland PNW Pasture Calendar Grassland Growth Periods.

Growth Period	Title	Brief Description
1	Semi-dormancy	Recovering from dormancy, initiation of and slow root growth.
2a	Steady fall regrowth	New apical meristems and green tillers with many brown leaves and medium root growth. Early phase of fall flush.
2b	Steady fall regrowth	Tillers mostly green with very little brown color with rapid root growth. Fall flush.
3a	Declining regrowth	Slowing plant top and root growth, tillers / leaves may yellow.
3b	Very slow growth	Plants are semi-dormant; maintenance growth and roots are shedding. Soil temps are about 41 °F (5 °C); pastures done for season.
4	Winter dormancy	Leaves and roots are shedding.
5a	Increased growth	Plants use stored reserves to increase generation of new shoots and roots. Soil temps about 41 °F (5 °C) pasture growth occurs.
5b	Increasing growth	Plants rapidly increase growth of establishing shoots and roots.
6a	Rapid growth -- cool soils	Plant uses reserves at a reduced rate with rapid root growth. Spring flush begins.
6b	Rapid growth – warm soils	Tops show rapid growth, high quality, rapid root growth, quality declines without harvest. Spring flush continues.
7	Slowing growth	Top growth slows, root growth slows dramatically, managed harvest maintains quality.
8a	Steady growth	Slowing top growth, root shedding begins.
8b	Slower steady growth	Less top growth, root shedding increases.
9	Slowed growth	Rapid root shedding, drought/heat starts summer dormancy.
10	Summer Dormancy	Dormancy occurs with continued root shedding; stubble mgmt. is critical for regrowth.

Introduction Chapter 7



The Inland Pasture Calendars

The following tables define 14 of the USDA-NRCS Major Land Resource Areas (MLRA's) by individual state in the Inland Pacific Northwest (PNW) region. Collectively the region is large, varies in elevation from about 650 ft (198 m) to greater than 8,000 ft (2,438 m) elevation. This elevation range results in annual moisture differences from 6 inches (152 mm) in the desert-like-areas to mountain valley floors and higher mountain meadows with 63 inches (1,600 mm). These wide environmental differences translate into differences in pasture grass growth and Growth Periods (Introduction Chapter 6). Within the Inland region, frost free days averages 160 (range 130-200) for MLRA 7 and 8 in the Columbia Basin and Plateau to 65 days or less for MLRA 43-44 in the mountains and higher elevations. Perennial cool-season grasses dominate Inland pastures, and their growth limits extend beyond those of more temperature sensitive plants. Cool season pasture grass species will grow and flourish regionally, where other plants cannot.

Even with such great regional diversity, there are several MLRA's that cross state lines. For example, all three states share MLRA 9, the Palouse Nes Perce Prairie, and MLRA 43-44, the Blue, Rocky, and Seven Devils Mountains and Valleys, where the three states most interconnect. Oregon and Idaho also share MLRA's 10, 11, and 25. Oregon and Washington also share MLRA's 6, 7 and 8. Individually, Idaho has seven, Oregon 13 and Washington five MLRA regionally.

Each MLRA has a different color, making it easier to follow those shared MLRA's between the states. The Calendars are separated as "average / dryland" and "optimal / irrigated" within all MLRA's, except 43-44, which is separated by elevation. Average / dryland pastures only receive annual precipitation from rain, sleet, hail, or snow. Optimal / irrigated pastures receive additional water or supplemental irrigation from winter snowpack that is stored in reservoirs and distributed to pastures through a series of canals, or is pumped from rivers, creeks, streams, or ground water. The Calendars represent pasture grass growth in fall, spring, and summer. Early fall is greatly influenced by supplemental irrigation water where dryland pastures depend on natural precipitation. Overlain on each MLRA by precipitation or elevation is the pasture grass Growth Periods, also by selected distinctive colors.

Inland pasture grass growth starts in the fall - September - as described in Introduction Chapters 1, 3, and 6. Because Inland PNW pastures are comprised of perennial grasses, legumes, and forbs (Appendix Chapter

4a, 4b, and 4c), management prior to this essential growth in Growth Period 2a and 2b, will influence plant strength and ability to regenerate new tissues for perennial pastures. Some MLRA pastures will enter fall as fully summer dormant (Growth Period 10), semi-dormant (Growth Period 1) or possibly slowed growth (Growth Period 9) or steady growth (Growth Period 8a or 8b), as described in Introduction Chapter 6.

Winter dormancy, Growth Period 4, is distinct in the Inland PNW. Rain, freezing rain, fog, freezing fog, and snow all occur in most Inland MLRA's during winter. Plant sugar reserves keep new growth tissues alive during Growth Period 4. New spring growth in Growth Period 5a and 5b originates from the sugars stored in the stubble, which were largely created during Growth Periods 2a, 2b, 3a and 3b.

The Calendars are based on avoiding overgrazing to maintain a minimum level of plant sugars for winter dormancy and initiation of spring growth. Often there is news about winter killing of forages; this does occur and often traces back to summer and fall mismanagement of those perennial pastures.

Summer dormancy, Growth Period 10, often occurs in the average / dryland pastures, not so much in optimal or irrigated pastures, unless the pasture is experiencing drought. Irrigated pasture will transition into slowing growth (Growth Period 7) and then steady growth (Growth Periods 8a and 8b). The pasture manager observes this slower growth, which is largely caused by grasses shedding roots. Roots shed rapidly and continue through Periods 7 and 8, which greatly reduces the plants' ability to take up water and nutrients. Irrigated pastures will continue growing, but at a much slower rate. Average / dryland pastures will transition into Growth Periods 9 and 10.

If irrigation water is restricted (due to droughty conditions) irrigated pastures can quickly transition into Growth Periods 9 and 10. When this occurs, irrigated pastures will start growth in Growth Period 1, semi-dormancy, then proceed into steady fall regrowth periods. Grazing during spring flush, Growth Periods 5b, 6a and 6b and fall flush, Growth Periods 2a, 2b, 3a and 3b, should be easy to manage, but requires management to optimize pasture growth and quality for high animal performance.

By following the pasture Growth Periods and the recommendations made within the Appendix Chapters and throughout this bulletin, overgrazing, weed invasion and winter kill should become a thing of the past.

Inland Washington Pasture Calendar

MLRA name	Eastern Slope		Columbia Basin		Columbia Plateau		Palouse and Nez Perce Prairies		Blue, Rocky and Seven Devils Mtns and Valleys	
	6		7		8		9		43 - 44	
MLRA number										
Elevation range:									high elevations low elevations	
* Soil moisture status during growing season	Average/ Dryland	Optimal/ Irrigated	Average/ Dryland	Optimal/ Irrigated	Average/ Dryland	Optimal/ Irrigated	Average/ Dryland	Optimal/ Irrigated	Average/ Dryland	
September **	10	2a	10	2a	10	2a	10	2a	9/10	9/2a
September **	10	2b	10/1	2a/2b	10 /1	2a /2b	10/1	2b	2a	2a/3a
October	1/2a	3a	1/2a	2b	1 /2a	2b	1/2a	3a	2a/2b	2b/3a
October	1/2b	3b	2a/2b	2b/3a	2a /2b	2b /3a	3a/3b	3b	3a	3a
November	4	3b	3a	3b	3a	3b	3a/3b	3b	4	4
November	4	4	4	4	4	4	4	4	4	4
December	4	4	4	4	4	4	4	4	4	4
December	4	4	4	4	4	4	4	4	4	4
January	4	4	4	4	4	4	4	4	4	4
January	4	4	4	4	4	4	4	4	4	4
February	4	4	4	4	4	4	4	4	4	4
February	4	4	5a	5a	4	4	4	4	4	4
March	5a	5a	5a	5b/6a	5a	5b /6a	4	4	4	5a
March	5b	5b	5b/6a	5b/6a	5b /6a	5b /6a	4	4	4/5a	5b
April	5b/6a	5b/6a	6a	6a	6a	6a	5a	5a	5a	5b
April	6a	6a	6a/6b	6a/6b	6a /6b	6a /6b	5a	5a	5a	5b
May	6a	6a	6b	6b	6b	6b	5b	5b	5b	6a
May	6b	6b	6b	6b	6b	6b	6a	6a	6a	6a
June	6b/7	6b	7	6b	7	6b	6b	6a	6a	6b
June	7/8a	7	7/8a	6b/7	7 /8a	6b /7	7/8a	6b7	6b	7
July	8b	8a	8a/8b	7/8a	8a /8b	7 /8a	8a/8b	7/8a	7	7
July **	9	8b	9/10	8a/8b	8b /9	8b	9	8a/8b	7	8a
August **	9/10	8b	10	8b	10	8b	10	8b	8a/8b	8b
August **	10	8b/2a	10	8b	10	8b	10	8b/2a	9	8b/9

* Dependent on soil moisture and precipitation.
 ** Water will maintain growth or break dormancy.
 NOTE: MLRA 6, 7, 8, 9 and 43 - 44 shared with OR
 NOTE: MLRA 9, 43 - 44 shared with ID

Inland Oregon Pasture Calendar

MLRA name	Eastern Slope		Columbia Basin		Columbia Plateau		Palouse and Nez Perce Prairies		Central Rocky and Blue Mountain Foothills		Snake River Plains		Lost River Valleys and Mountains	
	Average/ Dryland	Optimal / Irrigated	Average/ Dryland	Optimal / Irrigated	Average/ Dryland	Optimal / Irrigated	Average/ Dryland	Optimal / Irrigated	Average/ Dryland	Optimal / Irrigated	Average/ Dryland	Optimal / Irrigated	Average	Optimal / Irrigated
MLRA number	6		7		8		9		10		11		12	
Elevation range:											***			
* Soil moisture status during growing season														
September **	10	2a	10	2a	10	2a	10	2a	10	2a	10	2a	10/1	2a
September **	10	2b	10 / 1	2a / 2b	10/1	2a/2b	10/1	2b	10	2b	10	2a / 2b	1/2a	2b
October	1/2a	3a	1 / 2a	2b	1/2a	2b	1/2a	3a	1/2a	2b/3a	1/2a	2b/3a	2b	2b/3a
October	1/2b	3b	2a / 2b	2b / 3a	2a/2b	2b/3a	3b	3b	3b/4	3a/3b	1/2a	2b/3a	3a	3a
November	4	3b	3a	3b	3a	3b	3a/3b	3b	4	3b	3b	3a/3b	3b	3b
November	4	4	4	4	4	4	4	4	4	4	4	3b/4	4	4
December	4	4	4	4	4	4	4	4	4	4	4	4	4	4
December	4	4	4	4	4	4	4	4	4	4	4	4	4	4
January	4	4	4	4	4	4	4	4	4	4	4	4	4	4
January	4	4	4	4	4	4	4	4	4	4	4	4	4	4
February	4	4	4	4	4	4	4	4	4	4	4	4	4	4
February	4	4	5a	5a	4	4	4	4	4	4	4	4	4	4
March	5a	5a	5a	5b / 6a	5a	5b / 6a	5a	4	5a	5a	5a/5b	5a/5b	4	4
March	5b	5b	5b / 6a	5b / 6a	5b/6a	5b / 6a	4	4	5a	5a/5b	5b/6a	5b/6a	4	4
April	5b/6a	5b/6a	6a	6a	6a	6a	5a	5a	5b	5b/6a	5b/6a	5b/6a	5a	5a
April	6a	6a	6a / 6b	6a / 6b	6a/6b	6a/6b	5a	5a	5b/6a	6a	5b/6a	5b/6a	5b	5a/5b
May	6a	6a	6b	6b	6b	6b	5b	5b	6a	6b	6a/6b	6a/6b	6a	6a
May	6b	6b	6b	6b	6b	6b	6a	6a	6a	6b	6b	6b	6a/6b	6a
June	6b/7	6b	7	6b	7	6b	6b	6a	6a	6b	6b	6b	6b	6a/6b
June	7/8a	7	7 / 8a	6b / 7	7/8a	6b/7	7/8a	6b7	6b	6b	6b/7	6b/7	6b/7	6b/7
July	8b	8a	8a / 8b	7 / 8a	8a/8b	7/8a	8a/8b	7/8a	7/8	6b/7	8a	7/8a	7/8a	7
July **	9	8b	9 / 10	8a/8b	8b/9	8b	9	8a/8b	9	8a	9	8b	8b	7/8a
August **	9/10	8b	10	8b	10	8b	10	8b	10	8b	10	8b	9/10	8a
August **	10	8b/2a	10	8b	10	8b	10	8b/2a	10	8b	10	8b	10	8b/2a

* Dependent on soil moisture and precipitation.
 ** Water will maintain growth or break dormancy.
 *** Split cells denotes separation of western zone MLRA area 11 from eastern zone of MLRA area 11, respectively.
 NOTE: MLRA 6, 7, 8, 9 shared with WA
 NOTE: MLRA 9,10,11, 25 shared with ID
 Note: MLRA 21, 23 and 24 only found in OR

Inland Oregon Pasture Calendar (Cont.)

MLRA name	Eastern Idaho Plateaus		Klamath and Shasta Valley Basins		Malheur High Plateau		Humboldt Area		Owyhee High Plateau		Blue, Rocky and Seven Devils Mtns and Valleys	
	MLRA number	Elevation range:	MLRA number	Elevation range:	MLRA number	Elevation range:	MLRA number	Elevation range:	MLRA number	Elevation range:	high elevations	low elevations
* Soil moisture status during growing season	Average	Optimal / Irrigated	Average / Dryland	Optimal / Irrigated	Average / Dryland	Optimal / Irrigated	Average / Dryland	Optimal / Irrigated	Average / Dryland	Optimal / Irrigated	Average / Dryland	
September **	1/2a	2a	10	2a	10	2a/2b	10	2a	10	2a	9/10	9/2a
September **	2a	2b	10/1	2b	10/1	2b	10/1	2a	10/1	2b	2a	2a/3a
October	2b	2b/3a	2a/2b	2b/3a	1/2a	2b/3a	2a	2b	2a	2b	2a/2b	2b/3a
October	2b/3a	3b	3a/3b	3a/3b	2b/3a	3a	2b/3a	2b/3a	2a/2b	2b/3a	3a	3a
November	3b	4	4	4	3b	3b	3a	3a	2b/3a	3a	4	4
November	4	4	4	4	4	4	4	4	3b/4	3b/4	4	4
December	4	4	4	4	4	4	4	4	4	4	4	4
December	4	4	4	4	4	4	4	4	4	4	4	4
January	4	4	4	4	4	4	4	4	4	4	4	4
January	4	4	4	4	4	4	4	4	4	4	4	4
February	4	4	4	4	4	4	4	4	4	4	4	4
February	4	4	4	4	4	4	4	4	4/5a	4/5a	4	4
March	4	4	4	4	4	4	4	4	5a	5a	4	5a
March	4	5a	4/5a	4/5a	4/5a	4/5a	5a	5a/5b	5a	5a/5b	4/5a	5b
April	5a	5a/5b	5a	5a	5a/5b	5a/5b	5b	5b/6a	5b	5b	5a	5b
April	5a	5a/5b	5a/5b	5a/5b	5b	5b	5b	6a	5b/6a	5b/6a	5a	5b
May	5a/5b	5b	5b	5b/6a	5b/6a	5b/6a	6a	6a	6a	6a	5b	6a
May	5b	6a	5b/6a	6a	6a	6a	6a/6b	6b	6a/6b	6a/6b	6a	6a
June	6a	6a/6b	6a	6a/6b	6b	6b	6b	6b	6b	6b	6a	6b
June	6a/6b	6b	6b/7	6b/7	6b/7	6b/7	7/8a	6b/7	6b/7	6b/7	6b	7
July	6b/7	7	8a/8b	7/8a	7/8a	6b/7	8a	7	7/8a	7	7	7
July **	7/8a	7/8a	9	8a/8b	8b/9	7/8a	8b/9	8a	8a/8b	8a	7	8a
August **	8b/9	8b	10	8b	9/10	8a/8b	10	8b	9	8b	8a/8b	8b
August **	9/10	8b/2a	10	8b	10	8b/2a	10	8b/2a	10	8b/2a	9	8b/9

* Dependent on soil moisture and precipitation.
 ** Water will maintain growth or break dormancy.
 *** Split cells denotes separation of western zone MLRA area 11 from eastern zone of MLRA area 11, respectively.
 NOTE: MLRA 6, 7, 8, 9 shared with WA
 NOTE: MLRA 9/10, 11, 25 shared with ID
 Note: MLRA 21, 23 and 24 only found in OR

Inland Idaho Pasture Calendar

MLRA name	Palouse and Nez Perce Prairies		Central Rocky and Blue Mountain Foothills		Snake River Plains		Lost River Valleys and Mountains		Eastern Idaho Plateaus		Owyhee High Plateau		Blue, Rocky and Seven Devils Mtns and Valleys	
	9	10	11	12	13	25	43 - 44							
MLRA number	10		11		12		13		25		43 - 44			
Elevation range:	***		***		***		***		***		***		***	
* Soil moisture status during growing season	Average/Dryland	Optimal/Irrigated	Average/Dryland	Optimal/Irrigated	Average/Dryland	Optimal/Irrigated	Average/Dryland	Optimal/Irrigated	Average/Dryland	Optimal/Irrigated	Average/Dryland	Optimal/Irrigated	high elevations	low elevations
September **	10	2a	10	2a	10/1	2a	10/1	2a	1/2a	2a	10	2a	9/10	9/2a
September **	10/1	2b	10	2b	1/2a	2a	1/2a	2b	2a	2b	10/1	2b	2a	2a/3a
October	1/2a	3a	1/2a	2b/3a	2b	2b/3a	2b	2b/3a	2b	2b/3a	2a	2b	2a/2b	2b/3a
October	3a/3b	3b	1/2a	2b/3a	3a	2b/3a	3a	3a	2b/3a	3b	2a/2b	2b/3a	3a	3a
November	3a/3b	3b	3b	3a/3b	3b	3a/3b	3b	3b	3b	4	2b/3a	3a	4	4
November	4	4	4	3b/4	4	3b/4	4	4	4	4	3b/4	3b/4	4	4
December	4	4	4	4	4	4	4	4	4	4	4	4	4	4
December	4	4	4	4	4	4	4	4	4	4	4	4	4	4
January	4	4	4	4	4	4	4	4	4	4	4	4	4	4
January	4	4	4	4	4	4	4	4	4	4	4	4	4	4
February	4	4	4	4	4	4	4	4	4	4	4	4	4	4
February	4	4	4	4	4	4	4	4	4	4	4	4	4	4
March	4	4	4	4	4	4	4	4	4	4	4/5a	4/5a	4	4
March	4	4	4	5a	4	5a/5b	4	4	4	4	5a	5a	4	5a
March	4	4	4	5a/5b	4	5b/6a	4	4	4	4	5a	5a/5b	4/5a	5b
April	5a	5a	5b	5b/6a	5a	5b/6a	5a	5a	5a	5a/5b	5b	5b	5a	5b
April	5a	5a	5b	6a	5b	5b/6a	5b	5a	5a	5b/6a	5b/6a	5b	5a	5b
May	5b	5b	6a	6b	6a	6a/6b	6a	6a	5a/5b	5b	6a	6a	5b	6a
May	6a	6a	6a	6b	6a	6b	6a	6a	5b	6a	6a/6b	6a	6a	6a
June	6a	6a	6a	6b	6b	6b	6a	6a	6a	6a/6b	6b	6a	6a	6b
June	7/8a	6b/7	6b	6b/7	6b/7	6b/7	6b/7	6a/6b	6a/6b	6b	6b/7	6b/7	6b	7
July	8a/8b	7/8a	7/8	6b/7	7/8a	7/8a	7	7	7/8a	7	7/8a	7	7	7
July **	9	8a/8b	9	8a	8b	7/8a	7/8a	8b	7/8a	7/8a	8a/8b	8a	7	8a
August **	10	8b	10	8b	9/10	8b	9/10	8a	8b/9	8b	9	8b	8a/8b	8b
August **	10	8b/2a	10	8b	10	8b	10	8b/2a	9/10	8b/2a	10	8b/2a	9	8b/9

* Dependent on soil moisture and precipitation.

** Water will maintain growth or break dormancy.

*** Split cells denotes separation of the western zone of MLRA 11 / from eastern zone of MLRA 11, respectively.

NOTE: MLRA 10, 11, 25 shared with OR

NOTE: MLRA 9, 43 - 44 shared with OR and WA

NOTE: MLRA 12 and 13 only found in ID



Introduction Chapter 8

Summary of Calendar Growth Period Essentials

The following table summarizes key principles and management factors which are essential for best management practices for Inland region dominant perennial cool-season pasture grass growth by period. Grass Growth Periods precede the important autumn environmental cycle of reducing temperatures and daylengths, necessary for renewed perennial growth. Greater details for each factor are discussed within the Calendar. The 10 pasture Growth Periods over the 12 calendar months are variable

in length, sometimes lasting only a few weeks to multiple months. Not all periods are included in all Major Land Resource Areas (MLRA's) within the three states. The Inland region has extremes in temperatures, normal precipitation (rain to snow), length of growing season, soils, slopes, and elevation. The Appendix Chapters provide support, assistance, and explanation of growth and management interactions for sustainable pastures from the Inland PNW region. The following Growth Periods are shown by title and color as shown in the Introduction Chapters 6 and 7.

Period: 1 Growth Period name: Semi-dormancy

What is the grass doing?	Pastures will be recovering from dormancy. Pre-initiation of new, short root growth even when little above-ground living tissue is present. This early root growth starts slowly.
Environmental factors	Hot summer temperatures have mitigated, but lingering effects of summer dormancy remain. Nights cool and days shorten, but soils are warm, and weeds sprout when rains return.
Management needed	Care is needed to not overgraze because managers think plants are dormant. Stubble height is important as sugars promote new growth when conditions improve slightly. Acid soils can be limed without damage to soils or plants.
Things to avoid	Do not overgraze or mow below minimum stubble heights as this delay's new growth. Over fertilization may burn new growth as it appears.

Period: 2a Growth Period name: Steady fall regrowth

What is the grass doing?	New white to light green apical meristems is present at the crown and new white roots are growing. Brown leaves and stems from Period 1 should be present as these contribute sugars to this new growth. Early phase of fall flush growth occurs.
Environmental factors	Cooling soil temperatures and moist soils encourages early grass regrowth. Plants from Period 1 or 10 should be yellow tan to brown and not actively growing as pastures enter Period 2a. As new green leaves and roots start growing, older brown leaves should be covered quickly.
Management needed	If pasture soils were not tested in Period 1, test now. Acid soils can be limed but limit to one ton per acre or less per year on established pasture stands. Application of P and K enhances apical meristem development, which increases number of meristems.
Things to avoid	If liming acid soils, avoid increasing density by driving on wet/saturated soils during this period. Avoid over fertilization with N as this reduces plant sugars by over stimulation of pasture growth prior to winter, Period 4.

Period: 2b Growth Period name: Steady fall regrowth

What is the grass doing?	Growth from early apical meristems transitions into tiller leaves, e.g., full fall flush. Overgrazed plants should now start Period 2a. Few brown leaves remaining, mostly green with rapidly expanding root growth from tillers. Grasses continue to store sugars in stubble and lower leaves. Plant cells are smaller with thin walls so easy to digest and very palatable.
Environmental factors	Fall equinox occurs for all MLRA's. Cooling air and soil temperatures encourages grass growth. Shorter days decrease amount of photosynthesis time of pastures promoting steady growth.
Management needed	If P and K are needed and were not applied in Period 2a, they should be now. Graze new growth but not below residual stubble heights. Last opportunity to apply plant nutrients for uptake and use by new roots, leaves and additional tiller development.
Things to avoid	Avoid overgrazing as pasture quality will be highest of the growing season. High sugar content at stem bases is attractive to grazers. Moderate drought stress will increase sugar content. Avoid over fertilization with N, as this reduces plant stubble sugars, needed by grasses to avoid winterkill, through over stimulation of pasture growth prior to winter, Period 4.

Period: 3a Growth Period name: Declining growth

What is the grass doing?	Top leaf and root growth dramatically slows. Early fall leaves start to yellow; thus, N and S will mobilize to newer meristematic tissues. Tiller development slow dramatically with any new growth from small size mitotic cells. Root color is no longer bright white but becomes creamier to light tan.
Environmental factors	Air and soil temperatures decline rapidly. Shorter photoperiods result in less photosynthesis which contributes to declining growth. Fall rains keep soil organic matter moist that helps soil fungi and bacteria to decompose this organic matter.
Management needed	Saturated porous soils may start to leach key nutrients below crop rooting zone. Water or wind erosion may begin if stubble is short or bare soils occur.
Things to avoid	Avoid overgrazing as short stubble or bare soils can be subjected to wind or water erosion. Avoid applying nutrients except lime. Avoid over fertilization with N as this reduces plant sugars by over stimulation of pasture growth prior to winter, Period 4.

Period: 3b Growth Period name: Very slow growth

What is the grass doing?	Plants transition into semi-dormancy, leaf growth is stagnant. Roots will transition to shedding with tan colors dominating with some early roots browning.
Environmental factors	When soil temperatures reach about 41 °F (5 °C) pastures stop daily growth with marginal photosynthesis.
Management needed	Late plantings of pastures are possible when the period is near completion. This is like frost seeding in early spring.
Things to avoid	Avoid applying nutrients except lime. If planting late, don't want seeds to germinate, can but be incorporated with hoof action in Periods 4 and 5a.

Period: 4 Growth Period name: Winter dormancy

What is the grass doing?	All visible plant growth stopped, above and below ground. Apical meristems in crown are alive and sugars from stubble and above ground leaf tissues continue to feed this tissue. Roots shed as seen by color changes from creamy to tan to brown. Near the end of winter dormancy roots and soil organic matter will turn black and create humus.
Environmental factors	Freezing temperatures, rain and snow dominate daily weather. Periods of sunshine occur but low temperatures and slower moving low pressure systems continue the unstable conditions. Excellent time to start monitoring T-Sum weather conditions.
Management needed	Winter seems like a period when few management decisions are needed. This is not true. If feeding hay on pasture lands be aware livestock may eat stubble lower than recommended. This will delay spring green up (Period 5a) from two to six weeks. Harrow to spread manure at the conclusion of this period.
Things to avoid	Avoid leaving piles of remaining hay and manure around bale feeders. These materials are needed in the pasture for recycling and nutrient uptake later. Avoid early grazing this pastureland in the spring flush cycle.

Period: 5a Growth Period name: Increased growth

What is the grass doing?	New apical meristems and tillers from period 2a and 2b demand stored sugars for new growth. Soil temperatures above 41°F (5°C) growth occur. New roots will form from the apical meristems and use nutrients released from soil organic matter for spring growth. Pre- spring flush.
Environmental factors	Based on T-Sum and experience, fertilize pastures. Weather conditions will be unstable as fronts move quickly through the PNW. Spring rains and late winter snows occur. Warming temperatures increases soil microbial activity.
Management needed	Excellent time to fertilize with N and S, manure, compost, separated dairy solids, dairy lagoon water. Increased soil microbial activity mineralizes N and S so grasses can take them up for growth.
Things to avoid	Avoid over applying organic materials late in this period. Better to apply when growth begins so plant leaves can grow through to reach sun for photosynthesis.

Period: 5b Growth Period name: Increasing growth

What is the grass doing?	Grasses still depend on existing stored sugars for new growth. Rapid growth of existing leaf and root systems. If not grazed hard, leaf intercalary meristem will regrow quickly. Cell sizes are large which makes plant look like they are growing fast but growth is still very slow. Initiation of spring flush.
Environmental factors	Rains more frequent while snow events end. Periods of stable conditions and warming soils enhances soil microbial activity and root growth.
Management needed	If not fertilized in Period 5a then conduct those tasks in Period 5b. When irrigation water returns, apply to recharge soil moisture to field capacity. Maintain stubble heights for rapid regrowth after grazing while protecting soil from rain drop impacts. Rapidly rotate through pastures.
Things to avoid	Avoid overland water erosion on pastures as sediment and nutrients are needed on the soil for pasture plant growth. Bare soils will encourage existing weeds to start growing. Weed seeds can start to germinate.

Period: 6a Growth Period name: Rapid growth – cool soils

What is the grass doing?	Grass no longer dependent upon stored sugars for growth. Rapid cell division and elongation. Spring flush growth. Roots expanding rapidly, white color should dominate.
Environmental factors	Daylength increases, which contributes to greater hours of photosynthesis. Air temperatures warming but soils often less than 55 °F (12.8 °C). Fewer shower events.
Management needed	Irrigation season often begins, thus refill soil to field capacity. Rotate livestock rapidly, clip pasture after grazing to stimulate uniform regrowth for next grazing event.
Things to avoid	Avoid overgrazing, open / bare soil areas will encourage rapid weed growth and expansion. Soils will start to dry from the rapid pasture growth.

Period: 7 Growth Period name: Slowing growth

What is the grass doing?	Top growth slows while root growth dramatically slows. Possible early signs of root shedding. Regrowth from grazed or hay should continue but slower than periods 6a and 6b. Warm-season grass pastures increasing growth.
Environmental factors	Summer solstice. Temperatures are higher. Droughty conditions. High pressure systems dominate. Stable, often windless days and weeks.
Management needed	Irrigated to maintain field capacity of pastures. Fertilize with N and S if irrigation available.
Things to avoid	Avoid returning grazers to pastures too quickly. Avoid overgrazing to retain root growth as long as possible.

Period: 8a Growth Period name: Steady growth

What is the grass doing?	Root shedding begins, where roots change color from white / creamy to tan and brown. Soil microorganisms will decompose root mass from winter dormancy and current root shedding. Warm season pasture growth accelerating.
Environmental factors	Daylengths decreasing. Soil and air temperatures increase. High pressure dominates. Few if any showers. Soils drying. High evapotranspiration.
Management needed	Pastures can be damaged if mis-managed. Irrigate to maintain field capacity. Maintain minimum stubble heights. Root shedding and organic matter decomposition release nutrients for fall growth. Benefits to plant growth from water retained in soil organic matter.
Things to avoid	Avoid overgrazing.

Period: 8b Growth Period name: Slower steady growth

What is the grass doing?	Root shedding increases. Leaf tissues continue to grow from intercalary meristems, but most cool-season grasses will not joint again. Warm season grass growth at maximum daily rate.
Environmental factors	Daylengths decreasing. Soil and air temperatures are high, hot conditions. Soils dry rapidly. High evapotranspiration.
Management needed	Rotational grazing. Maintain minimum stubble heights. Root shedding. Organic matter decomposition release nutrients for fall growth. Irrigation sustains growth important for early apical meristem development in Period 1 and 2a.
Things to avoid	Avoid overgrazing.

Period: 9 Growth Period name: Slowed growth

What is the grass doing?	Rapid root shedding. Cool-season pasture growth has slowed greatly. Summer heat may initiate summer dormancy. Warm-season pasture growth at maximum daily rate with irrigation.
Environmental factors	Hot temperatures, dry soils, droughty conditions. Few scattered showers.
Management needed	Rotational grazing. Maintain minimum stubble heights. Root shedding and organic matter decomposition release nutrients for fall growth. If irrigation available, apply to meet evapotranspiration needs. Warm season irrigated pastures will continue to accumulate yield, likely will need to harvest hay now.
Things to avoid	Avoid overgrazing.

Period: 10 Growth Period name: Summer dormancy

What is the grass doing?	Pasture plants dormant above ground but apical meristems at crown are alive. Root shedding continues but slower because soils are often dry. Decomposition of roots maybe slower because of dry soils.
Environmental factors	Hot temperatures persist but cooling may start in some MLRA's. Few scattered showers. Very dry soils.
Management needed	Rotational grazing. Maintain minimum stubble heights. Pasture damage in period 10 could delay or skip Period 1 or 2a. Root shedding and organic matter decomposition release nutrients for fall growth. Irrigation maybe restricted in drought years forcing normally irrigated pastures into summer dormancy.
Things to avoid	Avoid overgrazing.

Appendix Chapter 1

Matching Pasture Production and Animal Demands

Christy Tanner and Don Llewellyn¹

The amount and quality of forage produced by pastures changes throughout the year due to seasonal differences in temperature and moisture, and physiological changes that occur in maturing forage plants. Forage production often does not line up with animal feed requirements throughout the year. This section will cover how the production and quality of different types of forage plants change over the year and how you can better match animal demand and plant production.

Forage production

Plant growth requires the availability of moisture, heat, and sunlight. These resources tend to change over the seasons. In many locations around the globe including the intermountain west, moisture tends to be scarce when heat and sunlight is plentiful and vice versa. Different groups of forage plants have developed different adaptations and strategies to manage limited resources. These different strategies result in different seasonal patterns of growth for cool-season vs. warm-season species, grasses vs. legumes, and annuals vs. perennials. Adjusting the amounts of these different types of forages on the farm can help achieve forage production that is better matched to animal demand (Figure 1).

Cool-season species are adapted to grow well when temperatures are low, but water is plentiful and can be used efficiently. Higher temperatures increase evapotranspiration rates so a plant has to use more water to grow. Cool season perennial grasses can begin growing when temperatures are around 41 °F (4.4 °C) and are most productive when temperatures are between 60 °F (15.6 °C) and 80 °F (26.7 °C). These grasses grow fastest when temperatures warm up in the spring. When temperatures peak in the summer, cool-season grasses are adapted to go dormant to survive limited water availability. Even with irrigation, growth will slow during what is often referred to as the “summer slump.” Production increases again when temperatures begin to cool in the fall.

Cool-season winter annuals primarily grow in the fall and spring, but compared to cool season perennials, the growth of annuals is shifted more toward the winter. This means they can be used to provide extra forage early

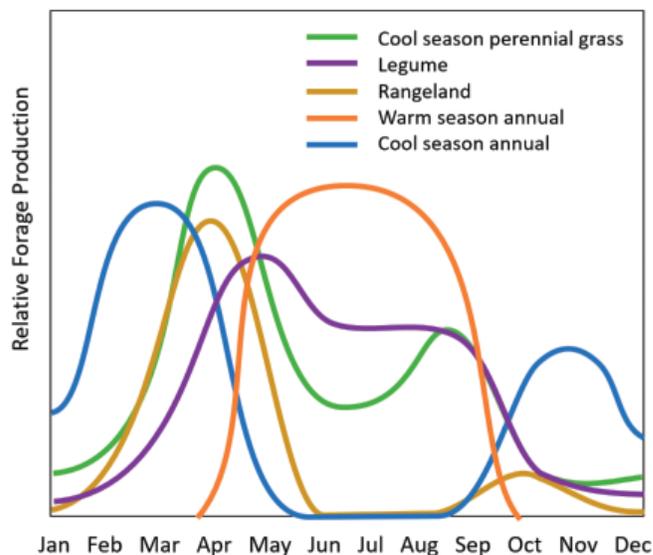


Figure 1 – Seasonal variation in forage production for groups of forages. Different types of forage are productive at different times of the year.

in the spring and later in the fall, extending the grazing season and reducing the need for hay.

Perennial legumes have deep tap roots that help them reach water stored deep in the soil profile, so they are able to maintain higher growth rates during the heat of the summer. Legumes such as clover and alfalfa tend to prefer warmer temperatures than cool season grasses. Legume growth follows a pattern that is similar to cool season grasses, but it begins later in the spring, ends earlier in the fall, and is more uniform throughout the summer, with a smaller drop in production in the heat of the summer.

Warm season species have adaptations that allow them to use water more efficiently during the summer. This allows them to take advantage of warm temperatures and abundant sunlight during mid-summer. Growing some warm season forages can help ensure that plenty of forage is available during the summer when cool season forages decline in productivity.

Rangelands are a source of forage for many livestock producers in the inland Pacific Northwest. Range adapted plant species often have a cool season growth strategy that allows them to utilize water from winter precipitation as the weather warms in the spring. In many areas, spring growth has largely completed by June because the plants run out of water. Fall forage production is dependent on precipitation and is often minimal. While forage production on the range occurs during a short time

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period, this forage is often utilized over a more extended period.

Forage quality

Forage quality depends on several interacting factors including temperature, forage maturity and leaf to stem ratio. Because forage quality declines as plants grow and mature (Figure 2), producers must balance trade-offs between forage yield and quality. Management factors including the timing and height of cutting or grazing can be used to help maintain more consistent forage quality.

Temperature is the most consistent factor controlling forage quality. During the high temperatures of midsummer, forage quality declines along with productivity of cool season perennial grasses and legumes during the “summer slump”. While quality changes in response to temperature occur within species, warm season species generally have lower quality than cool season species.

The tissues of forage plants differ in their forage quality. Leaves, where photosynthesis takes place, are generally high in protein because the machinery for photosynthesis is high in protein. Stems are low protein and high in fiber to fill their role in structurally supporting the leaves (Figure 3). Because of these differences, a leafy plant will have higher quality than a stemmy plant.

The ratio of leaves and stems changes as plants grow and mature (Figure 3). During initial growth or regrowth, leaves are preferentially produced so that the plant can photosynthesize. Next, the plant begins to produce stems to hold new leaves above the canopy. Eventually, leaf production begins to level off once the plant has a full canopy because higher, newer leaves will shade lower, older leaves, causing older leaves to die. Perennial ryegrass, for example, will have at most three leaves per stem. The timing of these changes differs between species. Cool season grasses will have about 50 % leaves and 50 % stems at the boot stage, while this will occur at the bud stage for legumes.

Both leaf and stem tissues decrease in quality as they mature due to changes cell wall composition. Cell contents are highly digestible and largely made up of non-structural carbohydrates, as well as fats and proteins. Cell walls are structural and made up of slowly digestible and indigestible compounds such as cellulose, hemicellulose and lignin. Primary cell walls form when cells first develop, but secondary cell walls form after the cell has grown to its final size and begins to mature. When secondary cell walls form, the amount of indigestible material accumulates including increased lignin in legumes and increased silica in cool season grasses (Figure 4). The quality of forages declines as they mature, but yield increases because the forage is growing.

Successful forage producers find a balance between yield and quality that meets the needs of their operations while also maintaining the health of their plants. The

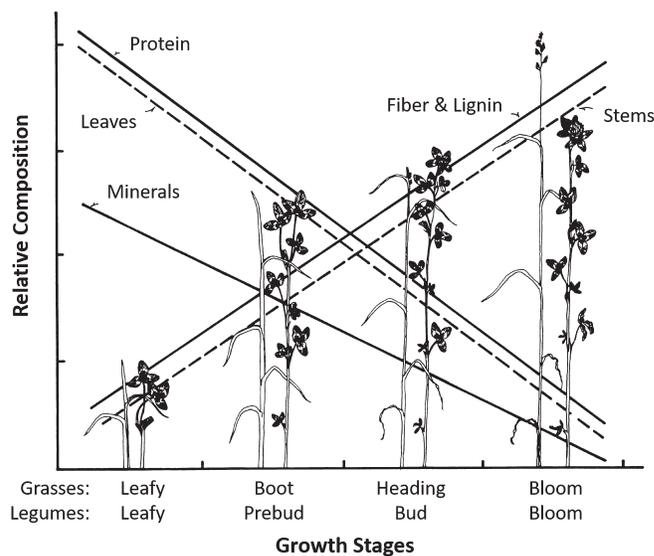


Figure 2. Relationships between forage maturity and quality. Source: Virginia Cooperative Extension, published in Blaser, R., R.C. Hammes, Jr., J.P. Fontenot, H.T. Bryant, C.E. Polan, D.D. Wolf, F.S. McClaugherty, R.G. Klein, and J.S. Moore. 1986. Forage–animal management systems. Virginia Polytechnic Institute, Bulletin 86-7.

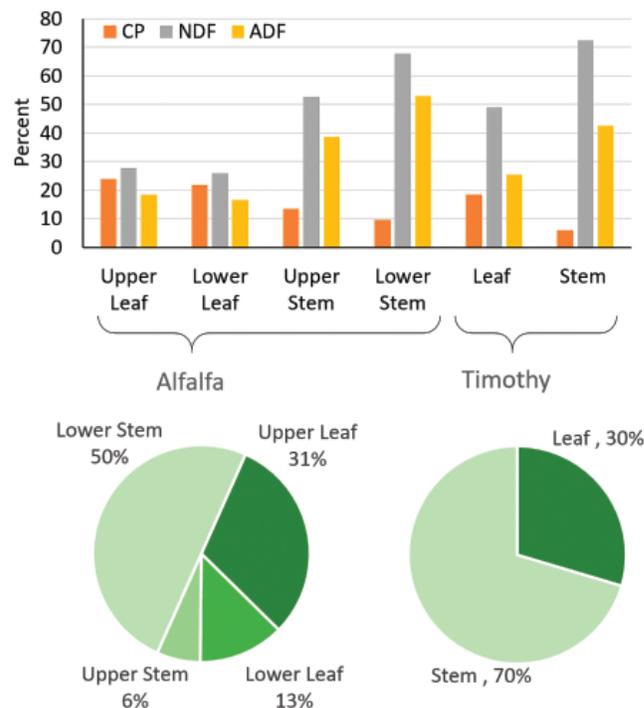


Figure 3. Distribution of forage quality throughout the plant. Top: Crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) percentages for leaves and stems. Bottom: Relative contribution of leaves and stems to whole plant biomass. Alfalfa was separated into upper (last five internodes of each stem) and lower portions before leaves and stems were separated. Source: Collins, M. 1988. Composition and fibre digestion in morphological components of an alfalfa-timothy sward. Anim. Feed Sci. Tech. 19:135–143.

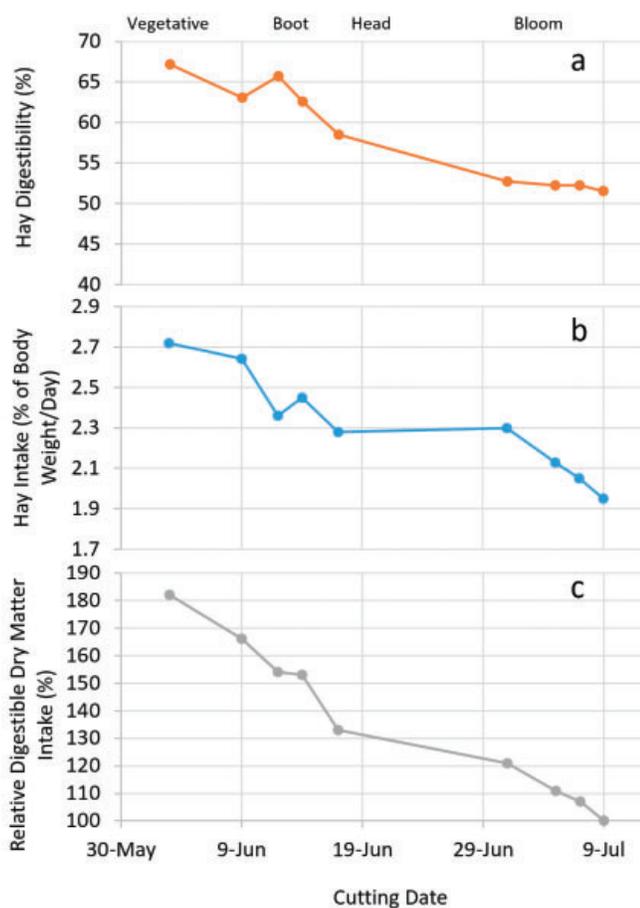


Figure 4. Hay digestibility (a), intake (b) and the relative intake of digestible dry matter (c) for grass hay harvested at nine different cutting dates spanning the vegetative stage to late bloom. Source: Stone, J.B., G.W. Trimberger, C.E. Henderson, J.T. Reid, K.L. Turk, J.K. Loosli. 1960. Forage Intake and Efficiency of Feed Utilization in Dairy Cattle. *J. Dairy Sci.* 43(9):1275-1281. <https://www.sciencedirect.com/science/article/pii/S0022030260903143?via%3Dihub> <https://www.sciencedirect.com/science/article/pii/S0022030260903143?via%3Dihub>.

best time to graze or harvest is generally when the forage has reached a peak growth rate, but before it shifts to reproductive growth. When pastures are grazed, it works well to have a target maximum height when grazing is started, and a target minimum height when animals are moved to another paddock. The target heights will depend on species, but for many species grazing should start at 8 to 10 inches and stop at 4 inches (Table 1). When harvesting hay, the best balance between yield and quality is when grasses are in the boot stage, and legumes are in the late bud stage.

Forage quality is unevenly distributed throughout the plant: the tops of plants are primarily high-quality leaves, while the lower portions of the plants are mostly fibrous stems (Figure 3). Cutting or grazing height will affect the quality and yield of forages. Raising the cutting height for hay will lower yield, but increase quality because

Table 1. When to begin and end grazing based on forage plant height.

Species	Forage height, inches (cm)	
	Begin Grazing	End Grazing
Tall growing cool season grasses and tall growing legumes	8 – 10 (20 – 25 cm)	4 (10 cm)
Ryegrasses	6 – 8 (15 – 20 cm)	2 (5 cm)
Short growing cool season grasses and legumes	4 – 6 (10 – 15 cm)	2 (5 cm)
Warm season grasses	12 – 14 (30 – 35 cm)	4 – 6 (10 – 15 cm)
Cereals	8 – 12 (20 – 30 cm)	3 – 4 (7.5 – 10 cm)

Adapted from Undersander, D., B. Albert, D. Cosgrove, D. Johnson, and P. Peterson, (2002). *Pastures for Profit: A guide to rotational grazing (A3529)*. Cooperative extension publishing. <https://learningstore.extension.wisc.edu/products/pastures-for-profit-a-guide-to-rotational-grazing-p96>

more low quality forage is left in the field. Animals that are allowed to selectively graze in a field or paddock over several days will consume the highest quality forage first. Over time, the quality of forage consumed will decrease until the animals are moved to a new paddock. Fluctuations in forage quality can influence animal performance and can be seen in fluctuations in milk production in dairy cattle. Animals will consume more uniform amounts and quality of forage if they are in a paddock for a shorter period of time.

Animal Demands

Perhaps the most important factor in achieving success in utilizing improved pastures is the thought process by which grazing/feeding programs are developed. The following are some key points to consider:

In achieving optimum productivity (with grazing animals) in forage based systems, producers of the major ruminant species all have the same general goals geared toward profitability: 1) feed economically; 2) reduce reproductive failure; and 3) keep the livestock healthy. The aforementioned goals are straight forward, but each has unique animal demands attached to it. To realize success in productivity, producers have at their disposal best management practices and technologies that can assist in supporting their goals. While the major ruminant species, cattle [beef and dairy], as well as small ruminants [sheep and goats] generally respond similarly to management strategies, it is essential to apply the technologies as appropriate to the various classes of animals (age, maturity, physiological status, time in the production cycle) as a subgroup within each species to match the nutrient requirements to the nutrient availability of the pasture at various times throughout the production cycle.

Recently, producers have become aware of the fact that providing nutrients to pregnant females at strategic times during gestation can influence productivity of the offspring after birth. This concept called epigenetics or commonly referred to as “fetal programming” has been shown to influence productivity later in life of both male and female offspring. Figure 5 shows the times in gestation during which key development of economically associated traits occur and it is apparent that maternal nutrition can affect muscle and fat development that in turn play an important role in both yield and quality of beef.

Another key element when determining if the nutrient demands of a ruminant are being met by the available forage is the recognition that in essence ruminant feeding programs are geared toward providing nutrition to the rumen microbes that in turn provide nutrition to the animal (i.e. energy and microbial protein). Meeting the rumen microbe’s requirement for protein and energy will ensure adequate delivery of nutrients to the host (i.e. cow, sheep, goat). Likewise, correcting for nutritional imbalances at the rumen microbe level is essential for optimum productivity.

When the nutrient requirements of grazing livestock exceed the available nutrients in the pasture, *supplementation* may be indicated. Supplementation is essentially a way to correct for nutritional imbalances. That is, provision of feed in addition to the available forage for grazing or harvested feed to correct for nutritional deficiencies. As noted previously, these deficiencies can be microbial or otherwise deficiencies to the host animal directly. It is important to note that provision of supplemental feed may correct for the imbalances directly. For example, a pasture that provides inadequate energy for the livestock may be supplemented with feed rich in energy such as corn, barley, or other grain. Alternatively, one can provide supplemental feed to enhance the utilization of the base forage. An example of this would be provision of limited amounts of ruminally degradable protein (RDP) to very low-quality forages in the winter. The provision of the RDP stimulates the work of the rumen microbial populations and in many cases increases intake and digestion of the base forage thereby delivering more energy to the animal. Figure 6 shows the relationship between season and the energy requirements of spring calving beef cows and appropriated times to consider supplementation to achieve production goals. Fall and winter supplementation are classic times to provide the additional nutrients. It is also notable that due to less-than-optimal management such as soil fertility, grazing strategies, and water availability, supplementation may be indicated during other parts of the year and different times in the production cycle (Figure 6).

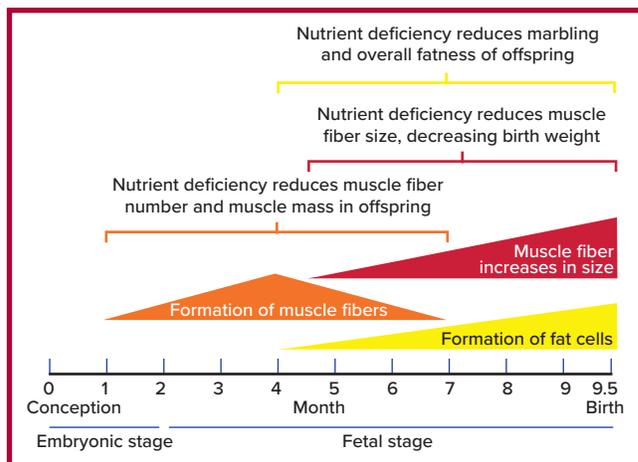


Figure 5. Nutrition of the pregnant cow: Mid-gestation is important for muscle fiber formation and late-gestation accounts for much of the increase in muscle fiber size. Mid-to late-gestation is critical for muscle fiber formation and growth, and late gestation are important for marbling development (Du et al., 2010).

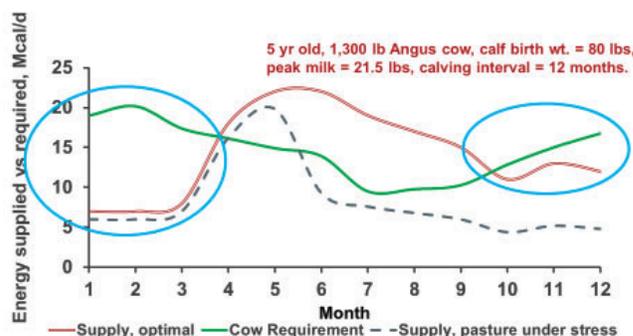


Figure 6. Matching the available forage energy resources to the nutrient requirements of spring-calving beef cows. The maroon-colored series shows the energy supply when management (i.e. fertilization, grazing, water supply) are optimal whereas the black-dashed series shows the potential reduction in nutrient supply when the pasture is under stress from less than optimal management. The blue circles depict the likely occurrences when the nutrient requirements exceed nutrient supply at which time supplementation may be indicated. This does not necessarily mean feeding extra energy at times encompassed in the blue circles. Also note that under stressful, less than optimal management conditions, that nutrient supply is less than the nutrient requirements for a significant part of the year. (Adapted from Marston, personal communication 2004).

Low quality forages present both a challenge and an opportunity for producers. The challenge is that in general they are typically not meeting the protein and energy requirements of the livestock. The opportunity is that ruminant livestock can economically utilize low quality forages in a very efficient way if adequately supplemented. An example of this scenario would be grazing or stockpiling of pastures that have reached

vegetative maturity. While the pasture may have provided good dry matter yield, it may be low or deficient in crude protein. This is particularly common in fall and winter pastures. Protein is usually the first-limiting nutrient in low quality forages, defined as forages with < 7 % crude protein. Not all full vegetative, mature pastures are this low in quality, this is particularly true of cool season grass species in the Pacific Northwest. The concept of the first-limiting nutrient means that if the first-limiting nutrient is not present in sufficient amounts in the forage, maximum productivity cannot be achieved even if all other nutrients are present to meet their requirements.

Producers often ask why livestock are more productive on high quality pastures or forages than when grazing low quality forages or crop residues. The answer to that question is based in “utilization” of the forage. Each forage is unique in chemical composition, and it is the chemical composition that defines the quality for the forage. It is essential to measure the forage quality of your pasture/forage by chemical analyses at various times throughout the growing season. Where the potential need for supplementation is concerned: “you don’t know what you need until you know what you have.” Forages are utilized to different extents based on the chemical composition. Young and immature plants are less fibrous and much more easily digestible. In general, young grasses are higher in protein as well. As grasses mature toward vegetative maturity, they also tend to accumulate anti-quality components such as silica, and phenolic compounds such as lignin all of which can chemically and physically inhibit degradation by rumen microbes leading to lower utilization and less energy delivered to the animal.

Supplementation of protein to livestock grazing or otherwise utilizing low quality forages has been shown to be very efficient (Llewellyn et al., 2006). The provision of limited amounts of RDP can unlock the energy in the base forage. Where improved pastures are concerned, what type of supplements can be used to provide supplemental protein? In the PNW, the classic protein supplement is alfalfa hay. Provision of alfalfa hay alone to ruminants overfeeds protein and is wasteful. However, when fed in limited amounts in conjunction with a low-quality hay or pasture, it is a great protein supplement. Likewise, other readily available feeds in the PNW can serve in the role as protein supplement, such as canola meal and dried distiller’s grains. Each can be fed to address protein deficiencies of late-season pastures and can usually be purchased for a reasonable price as this is written. Molasses-based supplements such as blocks and lick wheel tanks can serve the same purpose as the hand fed supplements when forage quality needs to be addressed.

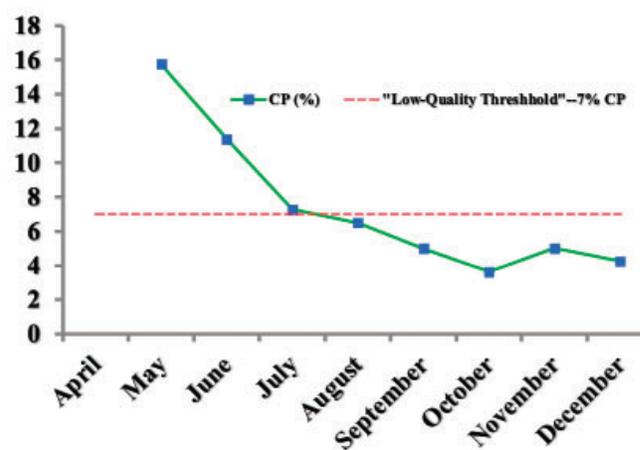


Figure 7. Seasonal changes in crude protein (CP; %) content of Bluebunch Wheatgrass across two years (1992 and 1993). Adapted from Ganskopp and Bohnert, 2001.

Finally, in some cases protein in the forage is adequate, but energy is deficient. In this circumstance an “energy supplement” may be indicated. It is also important to note that protein supplements can be mixed with energy supplements to balance for both protein and energy. Energy supplements can be found in several forms, but grains such as corn, barley, and triticale are typical energy supplements commonly used in the Pacific Northwest. An interesting dynamic in the use of energy supplements is that while they provide additional calories, they also reduce the efficiency of supplementation. In other words, they sometimes depress utilization of the base pasture/forage rather than only unlocking the potential of the forage and cause the energy feed to “substitute” for the forage. However, this dynamic can be used as a tool when wanting to extend the pasture resource or to increase stocking rate.

Managing pastures in the Northwestern United States requires an inexorable link between matching the nutrient requirements of livestock with the available forage, using techniques and technologies to increase forage utilization (getting the most out of the available forage), and managing in a way that is consistent with maintaining healthy forage resources into perpetuity (i.e. sustainability). Using beef cows as an example: Figure 7 depicts the seasonal changes in crude protein during the grazing season, (the dashed red line denotes 7% crude protein, below which is considered to be of low quality. During those periods forage quality may be low (i.e. crude protein content less than 7%) and cows may benefit from supplemental protein to satisfy the rumen microbes needs for nitrogen and thereby unlock more potential energy from the available forage as a result of increases in forage intake and/or digestion. Using Bluebunch Wheatgrass as an example, a significant portion

of the grazing season is characterized by only modest forage quality (less than 7 % CP). For spring calving cows in the third trimester of gestation, nutrient demand is low (pasture Growth Periods 3a, 3b, and 4). In fact, during this stage in the cows' production cycle, it is possible to realize very efficient body weight and body condition score gains when supplemented appropriately with protein (Llewellyn et al., 2006), even though the availability of protein in pastures during this period is typically deficient (Figure 7). Another key point is that for spring calving cows, forage quality is at optimum when calves are young and the cows' demand for protein are greatest with cows in early lactation (matching Growth Periods 6a and 6b). Shifting calving season to fall may have benefits for marketing, conserved forage and labor availability, or other reasons that apply to individual and unique operations. However, cows producing winter calves (i.e. born in November—January) will have the greatest demand for nutrients during pasture Growth Periods 4, 5a, and 5b requiring significant amounts of supplemental feeds for the cows and later for the calves until weaning. Upon weaning forage availability for fall

calves should be adequate in pasture Growth Periods 6a and 6b.

There is a temptation to “turn out” onto pastures too early (pasture Growth Periods 5a and 5b). This is especially true when supplemental winter and spring feed is expensive. However, the long-term implications may be costlier than otherwise expected: Reduction in total forage production for the grazing season; Potential for the detrimental effects of infestation of winter annuals in the pastures; Reduction in the animal carrying capacity; and finally, the cost of rehabilitation of those pastures to reestablish the favorable forage species. Time and patience are key to managing pastures. Allowing sufficient time for soils to warm and forages to establish new and viable root systems and have sufficient top growth (pasture Growth Periods 6a and 6b) will go a long way in achieving healthy and sustainable forages.

Meeting animal demands requires careful assessment (through observation and forage testing) of the amount and quality of available nutrients and then to match those resources to the nutrient requirements of the species and class of livestock utilizing the pasture. In doing so, optimum productivity can be achieved.

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Appendix Chapter 2

Rangeland and Pasture Integration

Tip Hudson¹

This appendix chapter on rangelands serves to supplement the Inland PNW Pasture Calendar for Eastern WA-OR and is not intended to be a comprehensive guide for sustainable rangeland grazing.

Rangelands have many different management considerations than irrigated pasture or dryland pasture with seeded “tame” grasses. These considerations include morphological differences in dominant forage species that require more careful grazing than sod-forming grass species in a mesic environment, habitat goals for wildlife species, terrain challenges, large areas unavailable geographically or topographically that could require significant effort or expense to graze, federal or state regulations governing use of public land, etc. There are important operational ties between rangelands and pasture, since many livestock producers in the Pacific Northwest use both land types, and we provide here a summary of grazing recommendations specifically for rangeland plant communities.

HOW ARE RANGELANDS DIFFERENT THAN PASTURE?

Rangeland is a type of land rather than a land use. Rangelands were historically defined by what they were not: not cropland, forestland, urban development, etc. But rangelands are more important ecologically and culturally than to be defined as the leftovers of humans’ land use. It is true that rangelands have always been defined by their marginality—economic, ecological, and even social marginality. Nathan Sayre in his 2017 book “Politics of Scale—A History of Rangeland Science” says that rangelands could well be defined as “those places where more intensive economic activities have not yet taken root” (Sayre, 2017). Nevertheless, the accepted current positive biological definition of rangelands is “land on which the indigenous vegetation (climax or natural potential) is predominantly grasses, grass-like plants, forbs, or shrubs and is managed as a natural ecosystem. If plants are introduced, they are managed similarly. Rangeland includes natural grasslands, savannas, shrublands, many deserts, tundras, alpine communities, marshes and meadows” (Bedell, 1998).

Rangelands in the Pacific Northwest are predominantly shrubland and grassland ecosystem types, with classic shrub-steppe comprised of various sagebrush species and bunchgrasses as the most common rangeland vegetation

type. Since most of the Intermountain West (IMW), east of the Cascade Mountains and west of the Rocky Mountains, has a wintertime precipitation pattern with very little effective precipitation arriving between April and October plants must survive on low soil moisture or use some means to access water deeper in the soil profile. Shrubs and bunchgrasses both have relatively deep root systems compared to most rhizomatous (sod-forming) grasses and even many trees found in more mesic ecoregions, which often have mostly shallow lateral stabilizing roots. These locally-adapted rangeland plants experience soil moisture when soil and air temperatures do not allow plant growth and growing temperatures when there is little soil moisture—yet they grow. Such is the life of a plant in a cold desert. Therefore, photosynthesis and rapid plant growth occurs between March 1 and July 1, later at higher elevations and earlier at very low elevations, with some growth also possible in fall where fall rains occur before freezing conditions.

BUNCHGRASS PHYSIOLOGY

The majority of bunchgrass species that are the skin of the earth over much of the IMW are jointed grasses, with elevated growing points that are sensitive to spring grazing. These species, like bluebunch wheatgrass, *Pseudoroegneria spicata* (Pursh) A. Love, the state grass of Washington, begin elongating their internodes, the sections of tissue between the nodes or growing points, in the spring after basal leaves have grown sufficiently, responding to temperature and daylength. For most of the IMW, this critical period for bunchgrass growth is around mid-April through mid-June. This window of time is called a critical period because if all the stems on a bunchgrass plant are grazed during this stage of growth, which we could call bolting, that plant may not produce seed that year. Since many bunchgrasses reproduce primarily by seed reproduction rather than vegetatively through sending out rhizomes or stolons, it is important for grazing managers to allow seed production in some years. A recent synthesis article examining the last fifty years of research on PNW bunchgrasses concluded that one of the only definitive factors for predicting long-term reproductive success and ecological persistence of the dominant bunchgrasses is whether grazing timing, duration, frequency, and intensity at a given site allows plants to produce seed every other or every third year (Burkhardt and Sanders, 2012).

Providing for seed production can be accomplished several different ways. A conservative stocking rate typically allows for a large proportion of plants in a rangeland pasture to remain ungrazed, such that many seed

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culms are never defoliated, and seed is produced even within a grazed area. Limiting the duration of the grazing period has a similar effect, i.e., grazing animals in a large pasture for only a month will not graze every plant when stocked at a sustainable animal density. More effective is changing the season of grazing use from year to year, even if just alternating use, such that a range area grazed in April and May this year would be grazed earlier or later than the critical period in the subsequent year. Floyd Reed, a retired US Forest Service range conservationist, has said that three rules of grazing management will maintain health on any type of rangeland:

1. Defoliate the primary forage species moderately.
2. Don't be in the same place at the same time every year.
3. Allow growing season recovery for every plant every year (Reed et al., 1999; Wyman et al., 2006).

INTEGRATING RANGE AND PASTURE

Livestock producers with access to both rangeland and tame dryland or irrigated pasture have useful opportunities to use the different land types to complement one another ecologically and operationally.

First, periods of ideal use may be usefully offset for range and pasture. For example, tame pasture, usually dominated by sod-forming species, grazed during the April-May flush tends to prolong vegetative production and delay reproductive growth, a desirable outcome on tame pasture. Helpfully, this allows rangeland forage plants to grow unimpeded during the critical growth period discussed above, allowing rangeland grasses to produce seed, at least some of the time.

Second, range grazing in fall and early winter keeps animals off tame pasture with softer soils and plants that may be fully grazed by the end of summer. Western U.S. bunchgrasses are said to "cure" well; this means they retain significant forage value into dormancy. Dormant season grazing on rangeland has several benefits to the plant community:

- Animal movement and hoof action promotes seed-to-soil contact, a common limiting factor in germination of perennial grass seed.

- Grazing dormant grasses does not negatively affect the subsequent year's growth, provided sufficient residual plant mass is left to support initiation of spring growth (usually >4" (10 cm) stubble on bunchgrasses).
- Recent research indicates fall and winter grazing may be effective in reducing density of invasive annual grasses the coming growing season (Perryman et al., 2018; Schmelzer et al., 2014).
- Late summer-fall grazing helps to break up standing dead material in plant crowns and facilitate litter-soil contact, litter providing soil protection from erosion and ameliorating soil temperatures during summer (Petersen et al., 2014; Wyffels et al., 2019).

Third, the typical diversity of rangeland plant species provides a broader array of both plant primary and secondary compounds, supporting animal health (Lisonbee et al., 2009; Provenza et al., 2007; Villalba et al., 2015). And on ranges with some toxic forbs such as certain lupine subspecies or larkspur (*Delphinium spp.*), grazing on irrigated pasture during the window of toxicity (on rangeland) avoids animal morbidity or mortality and allows grass growth.

Fourth, lower-elevation rangelands can be profitably grazed in winter with proper supplementation. Native bunchgrasses tend to be more structurally robust, standing up under light snow loads, and several rangeland shrubs such as antelope bitterbrush, *Purshia tridentata* (Pursh) DC, are nutritious in winter.

Fifth, when using grazing as a cultural control measure for various weeds or invasive grasses, one can use the forage type not being "treated" as a flexible feed source to move to once treatment objectives have been met.

The details on a specific ranch for a grazing plan that leverages both land types need to be site-specific, incorporating local weather constraints, plant phenology, weed concerns, habitat concerns, economic challenges, or opportunities, etc. Ranches with both rangelands and irrigated or tame dryland pasture should consult with other ranchers and local experts on how to best use these to their advantage.

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Appendix Chapter 3

Soil Nutrient Management and Importance for Inland PNW Perennial Forage / Pasture Systems

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The Essential Elements of Crop Growth

All plants require a variety of major pasture nutrients for their growth. Forage productivity and quality will be limited when any required nutrient is not available to the plant in adequate amounts. Nutrient deficiencies are most common for the primary nutrients nitrogen (N), phosphorus (P), and potassium (K) because they are needed in the largest amounts for plant growth. Secondary nutrients include Calcium (Ca), Magnesium (Mg), and Sulfur (S) (Potash and Phosphate Inst., 2003). Micronutrients needed for plant growth include Boron (B), Chloride (Cl), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), and Zinc (Zn). The elements sodium (Na), cobalt (Co) vanadium (V) and silicon (Si) are required for some plants but not for others. Fortunately, secondary and micronutrients are less likely to be deficient than the primary nutrients. County averages of micronutrients are available using USGS data at: <https://mrdata.usgs.gov/geochem/doc/averages/countydata.htm>, but you still need to soil test for your pasture for these elements. In the Pacific Northwest nutrients that most commonly limit pasture production are N, P, K, S, Zn, Fe, and B. This section gives general recommendations for fertilizer rates, your local extension office (state fertility guidelines) has information that is more appropriate for your local area.

Differences between pastures and hay fields

When plants grow, they absorb nutrients from the soil and incorporate them into growing leaves, stems and reproductive parts. If the forage is cut for hay, and removed from the field, the nutrients the forage contains are also removed from the field. If the forage is consumed by grazing animals in the pasture, some of the nutrients will be used for animal growth, but about 85 - 95 % of the N, P, K and other nutrients are returned to the soil in manure (Shewmaker, 2010). However, these nutrients

may not be well distributed. Imported feed or fertilizers are a source of nutrients to fields, and nutrients can be lost from the field through leaching, runoff, and erosion.

These differences in nutrient cycling and export between pastures and hayfields need to be accounted for in soil fertility management. Hay fields generally have higher fertilizer requirements because nutrients are removed when hay is harvested. The amount of nutrients removed in hay can be estimated based on yield and typical forage nutrient concentrations and replaced with fertilizer. In pastures, most nutrients stay in the pasture, but livestock can leave the most urine and dung near the water tank, shade, or salt, which increases soil nutrient levels in those areas. Rotational or management-intensive grazing systems can improve distribution of urine and manure nutrients compared to set stock grazing. Paddocks are designed no larger than 600 to 800 feet (183 – 244 meters) from water with no lanes, to greatly improve manure distribution and forage utilization rate within a paddock.

Soil testing

To determine if a field is nutrient deficient conduct a soil test. Soil tests measure the concentration of nutrients as determined by a specific soil test method. To determine how much fertilizer to apply, test results are compared to a calibrated nutrient concentration value that the plant needs to grow without yield loss. Soil testing should always be done before planting a pasture because it is easier to correct soil fertility issues when fertilizers can be tilled into the soil. Established pastures can be sampled every 2-3 years if the pasture is in good order – pH is not a problem, and all the nutrients are above critical nutrient levels. If the pH is outside of the recommended values or P, K or other nutrients are below critical nutrient levels, then soil testing should be done every other year.

The quality of the information you gain from a soil test depends on the quality of your sampling procedures (Fery, et al., 2018). Soil nutrient levels vary spatially from one part of the pasture to another, and between different soil depths. If you don't collect your soil sample carefully, you will likely get a sample that has either higher or lower nutrient levels than the pasture on average, which will lead you to apply too much or too little fertilizer. See the resources at the end of this appendix chapter for detailed information about how to collect soil samples.

If you collect a soil sample from the middle of a manure pile, or get more soil from high nutrient areas, you sample

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will have higher nutrient levels than your pasture on average. To account for spatial variability in your pasture, collect 13 subsamples distributed throughout your pasture and mix them together to get a sample that is close to the average of your sample area. If you can apply different amounts of fertilizer to different areas of your pasture, divide the pasture into areas that you expect to have different nutrient levels and submit a sample (made up of 13 subsamples) from each sample area to the lab for analysis.

Since pastures are rarely tilled, nutrients from manure tend to accumulate near the soil surface. If you collect your soil sample in a way that takes more soil from the surface than from deeper in the profile, your sample will have higher nutrient levels than your pasture. Using a soil probe that collects a cylindrical sample will help you get a uniform amount of soil throughout the depth you are sampling. Another important consideration is the depth to which you sample. Different soil fertility guides recommend different sampling depths for pastures because the nutrient recommendations were based on studies that used different sampling depths. You should always sample to the depth that matches the depth used in the fertilizer guide you are following. Many of the nutrient recommendations currently available for the inland Pacific Northwest were based on samples of the top 12 inches (30 cm) of soil, including those shown in tables 3 and 4. If you were to sample only the top 6 inches of soil, you sample would exclude the soil between 6- and 12-inches (15 - 30 cm) depth (which likely has lower nutrient levels). Thus, your sample would result in higher nutrient test results, and you may or may not apply enough fertilizer. Approximately 13 subsamples should be taken for each soil sample submitted to the laboratory no matter the size of the field to get a good representation of your pasture. A good rule of thumb is to take as many soil samples as you are willing to change fertilizer applied if recommendations come back different. To get more detailed information, can be found on the soil web survey (<https://casoilresource.lawr.ucdavis.edu/gmap/>). Avoid sampling in the middle of manure piles. Using a galvanized bucket will affect your zinc readings so use a plastic bucket for sample collection. It is advised that you send the soil sample into the laboratory rather than using a test kit as it more likely to get accurate results.

A list of laboratories that test soil can be found on the web at <http://analyticalabs.puyallup.wsu.edu/analyticalabs/services/> and under general services select soil fertility.

Labs serving Oregon can be found at <https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em8677.pdf>. A soil test will usually determine if pH, N, P, K, S, Zn, Cu, Mn, Mo, B, and sometimes Ca are lacking and will give a recommendation for your pasture or hay type.

The best way to monitor your soil fertility is to make a table and keep adding your soil test values to the table, whenever a new test is received. This way you can monitor whether pH or other nutrient levels are increasing, decreasing, or staying level over time. Use the same table to document your additions of fertilizer nutrients per acre annually as well as your annual yields or animal grazing days. If you would like to monitor closely nutrients leaving your field, you can test your hay for mineral nutrients. Add those to your table as well.

pH

Soil pH is one of the most important factors affecting soil fertility because it affects how easily plants can absorb the nutrients that are present in soil. A pH value of 7 means that the soil is neutral – neither acid nor alkaline. A lower pH value (< 7) means the soil is acidic while a higher pH value (> 7) means the soil is alkaline. If the soil is too alkaline, P, Ca, Fe, B, Cu and Zn become hard for plants to absorb, and if the soil is too acidic, P, Ca and Mg availability are decreased. The best overall nutrient availability is at pH 6.5-7, but different species and varieties have different ranges they can tolerate. Legumes such as alfalfa, trefoil, and clovers are sensitive to pH's below 6.5 since it affects the *Rhizobia* bacteria that fix nitrogen.

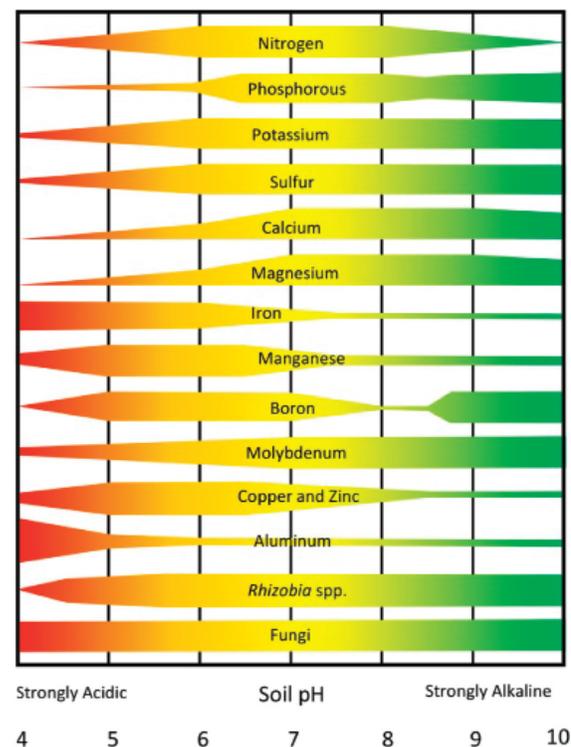


Figure 1. Availability of nutrients to forage as influenced by pH. An ideal pH is 7. The wider the line the more available (McFarland, 2015).

Grasses are less sensitive to acid soils and can tolerate to 6.0 pH, without yield decline. Soils tend to be more acidic near the surface and more alkaline lower down. If pH values are 6.0, sample the soil to 3 inches (8 cm) in depth and have it analyzed only for pH.

Soil amendments such as lime can change soil pH, though some soils change more easily than others. Many fertilizers will acidify soils over time (Table 1). If your soil is excessively acidic or alkaline you can change the pH by adding lime or elemental sulfur, respectively. If you want to increase the pH of an acidic soil, have a SMP Buffer analysis run on your 3-inch (8 cm) soil sample to determine how much lime is needed (Thompson et al., 2015a; Thompson et al., 2015b; Thompson et al., 2015c). Follow liming recommendations for your area, Idaho (Shewmaker, et. al., 2010), Oregon (Sullivan, 2013), or Washington (Thompson et al., 2016). The best time to address soil pH is before establishment and planting, Calendar Growth Periods 1 or 10, because you can incorporate the lime or sulfur. For established pastures do not apply more than 2 tons (1.8 Mg) of lime per acre, because you might make the soil surface too alkaline. The finer the lime material applied the faster it will affect the pH change in your soil. If your soil pH is between 8 – 8.5, decreasing pH with elemental sulfur is possible but most likely uneconomical (Horneck et al., 2007). Using ammonium sulfate or ammonium thiosulfate as a nitrogen source will help to reduce the pH over time. Calcium is the major component of lime, either Ag lime or dolomitic lime (which also contains Mg). Calcium is essential for the initial formation of pasture plant cell walls, e.g., yield. This cell wall component is called the middle lamella and is developed before cellulose, hemicellulose or lignin can be created for yield. This explains why it is essential to lime pastures that register lower than recommended in pH.

The results from Table 1 suggest small but consistent increases in lime demand per acre over years with different N sourced fertilizers. For example, if urea is used on a grass pasture with an equivalent score of 3.6 and 100 pounds/acre (112 kg/ha) of N were applied, the result is 360 pounds (163 kg) of lime demand. If this occurs annually for ten years then 3,600 pounds (1,633 kg) or more than 1.5 tons (1.4 Mg) of lime is needed to neutralize the acidity from the N, to maintain the current soil pH.

Table 1. Lime required to neutralize soil acidity from N fertilizers.^a

N – Fertilizer	Abbreviation	Analysis N-P ₂ O ₅ -K ₂ O-S	Lime needed to neutralize acidity (lb CaCO ₃ / lb N) ^b or (kg CaCO ₃ / kg N) ^b
Calcium nitrate	CN	9-0-0	0
Anhydrous ammonia	AA	82-0-0	3.6
Urea	-	46-0-0	3.6
Ammonium nitrate	AN	34-0-0	3.6
Urea ammonium nitrate	UAN	32-0-0	3.6
Ammonium polyphosphate	APP	10-34-0	7.2
Ammonium sulfate	AS	21-0-0-24S	7.2
Mono-ammonium phosphate	MAP	11-52-0	7.2
Ammonium thiosulfate	ATS	12-0-0-26S	10.8
Manure or compost	-	Variable	Variable

^a Lime requirement based on chemical reactions that convert fertilizer N to nitrate-N in soil, generating H⁺. This table is not a recommendation to apply lime in these amounts but to give relative acidifying characteristics as actual soil acidity produced in long-term fields is typically about half of the values listed here.

^b Lime requirement expressed as pounds of 100 score lime per pound of N applied product (or kg of 100 score lime per kg of N applied).

Source: Sullivan, 2013.

Nitrogen

Nitrogen is the most common limiting nutrient for pasture grasses. Unlike grasses, legumes do not need nitrogen fertilizer because they fix atmospheric N to plant proteins. With help from rhizobia bacteria, legumes can convert nitrogen gas (which cannot be used by plants), into forms of nitrogen that can be used by plants. Legumes require the appropriate inoculant to be placed on the seed at planting. Different legumes require a different species of rhizobia (NRCS, 2015). Since grasses and legumes differ in how much nitrogen fertilizer they need, your approach to fertilizing a pasture should vary depending on the ratio of grasses and legumes in the mix (Table 2). For all grass pastures, or those with less than 25% legumes, the fertility program should be focused on N fertility. Fertility programs for pastures that are at least 75% legume, should focus on P, K, and S fertility and no N should be applied. For mixed pastures, apply intermediate amounts of N and maintain adequate P and K levels. Applying extra N generally is an unnecessary expense. Fertilizer management that accounts for species composition will help maintain the desired species composition and will reduce weed problems or eliminate the need for nitrogen in your pasture. How much N you need to apply will also be determined by the productivity of your pasture (Koenig et al., 2002, Table 2). The timing and amount of your nitrogen application will influence the amount of grass vs. legume (balance) mix in your pasture. Early spring applications will favor the grass

Table 2. Nitrogen recommendations for a grass-legume pasture or hay field in English units.

Stand composition	Yield potential of the site			
	1-2 tons/acre	2-4 tons/acre	4-6 tons/acre	6-8 tons/acre
	nitrogen recommendation (lbs/acre)			
100% grass	50	75 ^a	100-150 ^a	150-200 ^a
75% grass, 25% legume	25	50	75-100	100-150 ^a
50% grass, 50% legume	0	25	50	75
25% grass, 75% legume	0	0	25	50

^aFor pasture, split the total nitrogen rate into two or three separate applications. Apply 1/3 to 1/2 of the nitrogen in early spring at the T-Sum 360 Fahrenheit time period (Calendar Period 5a), 1/3 to 1/2 in June (Calendar Period 6b), and the remainder in first two weeks of August (Calendar Period 10). Schedule mid- and late-season nitrogen applications to coincide with irrigation or rainfall events. For hay-pasture systems, apply 2/3 of the nitrogen in early spring and 1/3 after the hay crop is removed to stimulate regrowth for grazing.

Adapted from: Koenig, R., M. Nelson, J. Barnhill, and D. Miner. 2002 Fertilizer Management for Grass and Grass – Legume Mixtures. AG-FG-03. Utah State University Extension. https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1008&context=extension_histall Accessed 3/12/2020.

Table 2. Nitrogen recommendations for a grass-legume pasture or hay field.

Stand composition	Yield potential of the site			
	0.9-1.8 Mg/hectare	1.8-3.6 tons/acre	3.6-5.4 tons/acre	5.4-7.3 tons/acre
	nitrogen recommendation (kg/ha)			
100% grass	56	84 ^a	112-168 ^a	150-224 ^a
75% grass, 25% legume	28	56	84-112	112-168 ^a
50% grass, 50% legume	0	28	56	84
25% grass, 75% legume	0	0	28	56

^aFor pasture, split the total nitrogen rate into two or three separate applications. Apply 1/3 to 1/2 of the nitrogen in early spring at the T-Sum 100 Celsius time period (Calendar Period 5a), 1/3 to 1/2 in June (Calendar Period 6b), and the remainder in first two weeks of August (Calendar Period 10). Schedule mid- and late-season nitrogen applications to coincide with irrigation or rainfall events. For hay-pasture systems, apply 2/3 of the nitrogen in early spring and 1/3 after the hay crop is removed to stimulate regrowth for grazing.

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portion whereas later spring applications or no nitrogen applications will favor legume in the mix.

While this strategy will produce the most forage, one may have to bring in more animals to graze the additional forage. If forage growth exceed grazing demands you may harvest the additional forage for hay or silage one of the pastures.

Compared to other nutrients, nitrogen has a complex cycle in the environment; it is highly mobile and has multiple chemical forms. If nitrogen is applied at the wrong time, or at too high of a rate, it can be lost from the field without benefiting plant growth. Nitrate, the form of nitrogen that is easiest for plants to absorb, soils can acidify, dissolve in water and can be eluted from the soil with excessive irrigation or winter rain. To also reduce nitrate losses, N applications should be reduced

in the fall to increase grass stubble sugars to promote winter survival and promote early spring growth through avoiding overgrazing in the fall and winter dormancy period (growth period 4).

Urea is the most used N fertilizer, but it is prone to volatilization losses, especially if applied to warm or wet soil and plants, and newly burned pastures (Holcomb and Horneck, 2017; Rogers et al., 2019; Biswanath, et al. 2019). These losses can be reduced by applying 0.5 inches (1.27 cm) of irrigation after you fertilize. Nitrogen losses can be large with ammonia-based fertilizer applications, so it is best, to incorporate the fertilizer with 0.5 inch (1.27 cm) of irrigation which will reduce volatilization (Biswanath, et al. 2019). If you will not be able to incorporate the fertilizer, use urea with a coating such as MBPT (Agratain™) to reduce losses (Holcomb and Horneck, 2017; Rogers et al., 2019). This coating will greatly reduce volatilization for up to one month.

Fertigation

Nutrients can be applied through sprinkler irrigation but will only be as even as the irrigation water is applied. Although the US EPA does not regulate fertigation (it does regulate chemigation), the use of fertilizers for fertigation

may be subject to state laws and rules. Backflow prevention on the irrigation system is necessary to ensure fertilizer does not go back down wells or into the irrigation supply system. Applying fertilizer through pivots and linears distributes the fertilizer much more evenly across the pasture than wheel-line and hand-line type systems. Wind is the enemy of all irrigation systems in applying water evenly across the landscape.

Pricing Fertilizer

Price fertilizer liquid and dry and comparing the two on a \$ per pound (\$/kg) of N, P₂O₅, K₂O basis. There is enough water in the soil that liquid and dry are equally effective when applied to the soil. Also consider the cost to apply fertilizer when planning which source to purchase.

Phosphorus

The amount of phosphorus needed to grow legumes is higher than what is needed for grasses. However, both may respond to P fertilization in pastures and hay fields. Dual-purpose of haying and pasture grazing will place a higher requirement for root regeneration, root growth and P fertilization. Fall (Growth Period 1 and 2a, 2b) is the best time to apply P as it will help in tiller and bud formation which can improve productivity. If necessary, P can also be applied in the spring. Purple coloration and stunted root and shoot growth are signs of P deficiency. Phosphate adsorbs to the soil, so P fertilizers will not be lost due to leaching. However, some loss will occur due to P becoming fixed to soil particles; yet losses are generally low enough that multiple years of P can be applied.

Different soil P analysis methods are used depending on the pH of your soil. When testing soils with higher in pH (e.g. calcareous soils), the Olsen P method is recommended, whereas in acidic soils (< pH 7), the Bray method is most accurate. Be sure to request the method that works best for your pasture. Phosphorus availability in soil is highest between pH 6.5 and 7.5. Critical nutrient levels are 15 ppm (15 mg/kg) for grasses, and 20 ppm (mg/kg) for alfalfa. If economics allow, it is recommended to improve and maintain soil test P at 20-25 ppm (20-25 mg/kg). Recommended rates of P₂O₅ for pastures can be found in publications in your local extension offices and in Table 3. (Shewmaker et al., 2010).

Mono-ammonium phosphate (MAP) is a commonly used form of phosphate fertilizer. Struvite is a newer P fertilizer source that is made from municipalities and dairy lagoon waste. Research has shown that it is as effective as mono-ammonium phosphate (MAP) in applications to alfalfa and has a lower salt index and heavy metal content than commercial N P K fertilizers and it is believed to have a lower acidification rate of soil compared with MAP (Norberg, 2020; Latifian et. al., 2011).

Potassium

Potassium should be applied in Period 1 and 2a, 2b. The largest need for K is for the first cutting when soils are cold so fall or early spring applications are best. Large K

Table 3. Phosphorus (lbs P₂O₅/acre) recommendations for grass and legume pastures in the interior Columbia Basin (Shewmaker, et al., 2010).

Soil Test P ^a (ppm or mg/kg)	P Recommendation ^{b,c}			
	Irrigated (lb P ₂ O ₅ /acre)	Rainfed (lb P ₂ O ₅ /acre)	Irrigated (kg P ₂ O ₅ /ha)	Rainfed (kg P ₂ O ₅ /ha)
0 to 3	100 to 125	60 to 100	112 to 125	67 to 112
4 to 7	75 to 100	40 to 60	84 to 112	45 to 67
8 to 10	50 to 75	20 to 40	56 to 84	22 to 45
11 to 15	0 to 50	10 to 20	0 to 56	11 to 22
15 and above	0	0	0	0

^a Soil test P is based on a 12-inch (30.4 cm) sample depth and sodium bicarbonate soil extract (Olsen method).

^bFertilizer labels are expressed in percent P₂O₅. To convert P₂O₅ to P, multiply by 0.44.

^c Refer to local fertilizer guides for more specific recommendations.

Table 4. Potassium (lbs K₂O/acre) rates based on parts per million K in the soil for grass and grass legume pastures.

Soil Test K ^a (ppm in the soil)	K Fertilizer Recommendation ^b (lb K ₂ O/acre)	K Fertilizer Recommendation ^b (kg K ₂ O/hectare)
0 to 40 ^c	180 to 220	202 to 246
40 to 70	140 to 180	157 to 202
70 to 100	80 to 120	90 to 134
100 to 150	40 to 60	45 to 67
Above 150	0	0

^aSoil test K is based on a 12-inch (30 cm) sample depth and sodium bicarbonate soil extract. Sodium acetate or ammonium acetate extraction should give similar results.

^bK is expressed as both the oxide and elemental forms: K₂O x 0.83 = K or K x 1.20 = K₂O.

^c Low testing soils are severely limiting.

Source: Koenig, R., M. Nelson, J. Barnhill, and D. Miner. 2002 Fertilizer Management for Grass and Grass – Legume Mixtures. AG-FG-03. Utah State University Extension. https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1008&context=extension_histall Accessed 3/12/2020.

applications can be split into late-summer applications. Like phosphate, potassium is especially important for legumes, also important to grass fields. Potassium is important for water transport and metabolic functions and needs to make up around 2% to 2.5% of forage dry matter. Potassium is an element that is used by both grass and legume plants, which are luxury consumers of potassium, meaning they will take up more than they need for growth if it is available in the soil. Excess potassium in forages can lead to unnecessary K export in harvested hay and can negatively impact animal health. To maintain yield and quality of forage. Plant percentage K may be a better indicator of K sufficiency compared to soil test K, but both tests are valuable in helping to make K fertilizer application decisions. Applying more K when not needed will only result in more uptake of K than the plants need and be a negative return on dollars spent on K fertilizer.

Soil texture and depth may make a difference in the soil K reservoir, but K sufficiency level is 150 ppm (150 mg/kg), above that level, no K should be applied. The largest need for K is for the first cutting when soils are cold, so fall or early spring applications are best. Soils that are harvested for hay are more likely to become deficient. The two main potassium fertilizers are potassium chloride (0-0-60 and 0-0-62) and potassium sulfate (0-0-50) with potassium chloride being the more economical. Potassium sulfate is used where sulfur is also limiting. The most popular tests for K in the soil include sodium acetate, and ammonium acetate methods, which will give similar test results (Table 4).

Sulfur

Sulfur is limiting in some areas of the Inland Pacific Northwest, such as the Columbia Basin. Other areas, including those irrigated from the Snake River, have adequate sulfur levels. Like N and B, S moves with water. Over irrigation or high precipitation can leach S below the rootzone, resulting in deficiency. A target of N:S ratio of 10:1 in the soil should be kept in mind when determining pasture sulfur fertilization needs. In general, if the soil is less than 10 ppm (10 mg/kg) sulfate-S of 20 to 30 lbs of S per acre (22.4 - 33.6 kg/na) is recommended. Sources of sulfur include ammonium sulfate (24 % sulfur), potassium sulfate (18 % sulfur), gypsum (17 % sulfur) and elemental sulfur (90 % sulfur). Elemental sulfur has a couple of advantages in that it is slow releasing and so not as readily leached. If there are legumes in the pasture, gypsum is an excellent source of sulfur, along with the calcium that legume plants can benefit from, as well as the grass plants.

Selenium

While selenium is not required by plants, it is important for livestock health. Livestock can suffer serious health problems, such as white muscle disease, from selenium deficiencies, but too much selenium is also toxic. Soil selenium levels range from excessive in some areas to deficient in others, and this variation is reflected in the forages grown there. One way to correct selenium deficiencies in livestock is by applying a selenium soil amendment to pastures. Plant uptake of the selenium changes it into a more bioavailable and usable form more readily absorbed or utilized by the animal. Alternatively, livestock can be fed a mineral supplement containing selenium, but this must be done continuously. Livestock nutritionists tend to recommend the mineral supplements, especially in range situations. It is an accepted practice in Oregon to apply selenium to pastures. Selenium application is more tightly regulated in Idaho and Washington. In Idaho selenium is considered a heavy metal and cannot exceed certain levels. In Washington

selenium should only be applied by itself, not blended with other fertilizers or pesticides.

Selenium is mobile in the soil. Five to 10g of actual selenium per acre to achieve adequate levels of Se in forage (Brummer et al., 2014). Sodium selenate and Selcote Ultra® (Sodium Selenite) are a couple of sources one can apply. Sodium selenate contains 41 % Se and Selcote Ultra® contains 1% selenium or 4.5 grams per pound (454 g). Selcote Ultra® product recommendation is to apply 1.1 lbs/ac (1.2 kg/ha) for annual application or 2.2 lbs/acre (2.5 kg/ha) for every other year application. Most of the selenium from sodium selenite application will be absorbed by the plants early in the growing season. If a more even uptake of selenium is needed, then split applications will be necessary.

Micronutrients

Micronutrient deficiencies are uncommon, but they have been documented for zinc, iron, copper, manganese, and boron in the Inland Pacific Northwest. Table 5 shows the soil test levels that are adequate for these micronutrients and fertilizer application rates for soils that are below these levels. Since it is difficult to apply low amounts of these fertilizers per acre, micronutrients are normally mixed with K or P and applied together. Do not apply high rates of boron as it is toxic to plants.

Table 5. Micronutrient soil test values (ppm or mg/kg) and interpretations.

Nutrient	Low ^a	Marginal ^a	Adequate
Zinc	<0.8	0.8-1.0	>1.0
Iron	<3.0	3.0-5.0	>5.0
Copper	<0.2	–	>0.2
Manganese	<1.0	–	>1.0
Boron	<0.25	0.25-0.5	>0.5

^aIf soil tests indicate a deficiency, apply 5 lbs/acre (6 kg/ha) (for marginal levels) to 10 lbs/acre (11 kg/ha) (for low levels) lbs of zinc, manganese, or iron, or 1 lbs/acre (1 kg/ha) (for marginal) to 2 lbs/acre (2 kg/ha) (for low) of copper or boron.

DTPA extractable zinc, iron, copper, and manganese; hot water extractable boron.

Source: Koenig, R., M. Nelson, J. Barnhill, and D. Miner. 2002 Fertilizer Management for Grass and Grass – Legume Mixtures. AG-FG-03. Utah State University Extension. <https://extension.usu.edu/waterquality/files-ou/Agriculture-and-Water-Quality/Fertilizer/AG-FG-03.pdf>. Accessed 3/12/2020.

Timing of fertilizer application

The ideal timing for fertilizer application depends on what nutrients you are applying. Nutrients that are soluble in water (N, S, and B) should be in the spring. When these nutrients are applied in the fall, winter rains can leach these nutrients out of the soil profile before plants have a chance to use them. Applying high rates of N in the fall can reduce forage stands because excess N

prevents plants from preparing for winter dormancy. Fall applications of P and K are acceptable.

Choosing Fertilizer

Fertilizers must disclose the amount of nutrients they contain, per state Department of Agriculture requirements. This information is often shown as three numbers separated by dashes that represent the percentage of the fertilizer made up of N, P₂O₅, and K₂O, respectively. If there is a 4th number, it will generally be for S. For example, MAP is labeled 11-52-0, meaning it is 11 % N, 52 % phosphate and 0 % potash. If you apply 100 pounds (45 kg) of mono-ammonium phosphate, you are only applying 52 pounds (24 kg) of phosphate. Ammonium sulfate, for example, will be labeled 21-0-0-24S. This information is important when calculating how much fertilizer you need to buy and spread on your field. It is also helpful if you are comparing the cost of different fertilizers. When choosing fertilizer, also consider the cost of application. Liquid and dry forms of fertilizer are equally effective, but require different equipment to apply.

Fertilizer Application and Distribution

Fertilizer will be more effective at increasing the productivity of your pastures if it is uniformly distributed. If the fertilizer isn't spread evenly, some areas won't get enough fertilizer and will have low yields. Areas that receive extra fertilizer will produce at their full potential, but the extra fertilizer will go to waste because it was not needed.

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When applying fertilizer, ask questions if you use a fertilizer cart from a fertilizer dealer. What is the distance you should be driving from the previous pass? Has the cart been calibrated? What is the correct application pattern? Some spinner spreaders have a pyramid across the width. If it is a pyramid, then you must have a 50 % overlap of your previous pass. If you have your own fertilizer spreader information on calibration can be found in the owner's manual and in guide sheets such as this one. (Colley et al. 2018)

<https://ohioline.osu.edu/factsheet/fabe-561>.

Summary

Pasture plants need sunshine, water, and nutrients to grow and if water and or nutrients are both missing, then pasture productivity will be reduced. This often leading to overgrazing, which then leads to a demand for alternative feedstuffs when pastures could be providing less expensive feed. The lower the soil test level the more likely the yield will be limited by a specific nutrient. One nutrient that is deficient or limiting can cancel the benefit of other nutrients being applied, like nitrogen. So, diligence in doing a complete soil test is necessary. Farmers often apply more P fertilizer during good economic times and utilize the existing nutrients previously applied when bad economic times come. However, this P can become tied up and become unavailable. Since plants are luxury consumers of K, utilizing existing soil levels may reduce hay yields. If soil test levels are low, this does not work as yields will be limited; however, if levels are near optimum levels, it will work well.

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Appendix Chapter 4a

Grass Species for Dryland and Irrigated Pasture Management in the Inland PNW

Mysten Bohle, Joseph Sagers, Steve Norberg, Brendan Brazee, and Guojie Wang¹

Note: The following list of species summarizes their attributes and most of the information is directly from the USDA NRCS plant fact sheet database. For more in-depth review of each species, go to the link listed at the end of each species; also go to the reference section for more information.

When you are selecting species for planting a new pasture or hay field, or renovating an old pasture or hay field, there are many factors to consider:

- **Use and utilization.** Will this field be utilized for pasture, hay, silage, or dual purpose for pasture and conserved forage?
- **Seasonal use of pasture.** What time of year will you be grazing this pasture (winter, spring, summer, or fall)? Will you graze part of the year or all of the year? Will you harvest hay and then use it for pasture? Will you stockpile some forage for later grazing? This will make a difference in the species you select to plant.
- **Mixed grasses with or without legumes and or forbs vs. monoculture.** Is this pasture going to be a grass mixture with multiple grass species or a grass monoculture, where only one species of grass, perhaps with one legume and forb, is planted? Will you mix multiple species of grasses, legumes, and forbs? Grass species mixtures work well for management-intensive grazing, strip grazing, and rotational grazing because you are controlling the grazing time and use. With these types of grazing management, palatability is not as important in mixes. Mixtures also increase biodiversity in the soil which improves soil health. Palatability really needs to be considered if one is using a mixture of species with a set-stocking rate. Planting a single specie with or without a legume, is a much more manageable system for set stock grazing.
- **Mixing grass, legume, and forb species.** Planting legume species with grass species can create a higher feed quality, add to the grazing choices for livestock, and reduce the nitrogen fertilizer requirements of grass pastures. Adding legumes may dramatically reduce the need for nitrogen fertilizer long term once a grass/legume pasture is established. Adding forbs and legumes further increases herbage diversity, which increases soil health and forage quality, and may reduce the number of parasites due secondary metabolites, e.g., condensed tannins or bloat in these species mixtures.
- **Irrigation and Rainfall.** Choosing the right species of grasses, legumes, and forbs for different “precipitation climates” is important. Under full season irrigation, drought tolerance is not important. However, if irrigation water runs out in mid-summer, it is a very important factor to consider. Giving up a little yield potential to increase stand longevity could be a very important economic decision. It is important to choose species or varieties that are adapted to the amount of precipitation so the pasture can persevere through seasons of drought or flooding.
- **Soil fertility.** Plant growth is directly impacted by the amount of available nutrients in the soil. Soils can be tested for many variables, including pH, organic matter, soluble salts, as well as macronutrients and micronutrients. Soil testing is especially important for irrigated pastures prior to planting, but it is also important to monitor over time in any pasture, regardless of rainfall or irrigation. Soil testing before planting a pasture will provide the information needed to know if the soil pH can economically be ameliorated (with lime or sulfur). Economics plays a large role in how much the pH of a soil can be improved. Nutrients might need to be added initially as well as throughout the life of the pasture. Macronutrients such as nitrogen, phosphorus and potassium are often added in larger quantities or more frequently than micronutrients. Some species can tolerate lesser fertility, and all species have their best range of soil pH to which they are adapted.
- **Soil depth and texture.** Soil depth and texture is important to know. This can be done with a texture soil analysis test specifically, or by looking on the NRCS Web Soil Survey (<https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>) for your area to get a general idea. Different species of grasses, legumes and

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forbs have narrow to very broad soil textures ranges where they will grow best. The soil depth, along with soil texture and soil organic matter, makes up the reservoir for water holding capacity as well as for the root system to grow. Some species can tolerate shallow soils while others do better with deeper soils.

- **Aspect and slope of landscape.** Planting a field with a southern or northern aspect can make a difference how the plant will grow and produce. Plants growing on a southern aspect will green-up sooner and utilize the available soil moisture sooner than on northern aspects. Slope will dictate whether to plant bunchgrasses or rhizomatous grasses in consideration of possible soil erosion. It may also determine whether or not you add certain legume or forb species on dryland pastures to match areas of the pasture with varying soil moisture.
- **Elevation.** When selecting a species, the elevation may determine the pasture's winter hardiness, ability to handle snow cover or no snow cover, ability to handle frosts, and will have a major effect on length of growing season.
- **Control of existing plants.** The decision needs to be made if the entire pasture must be tilled out or if seed can be inter-seeded with the species already present. It is easier to introduce new plants into an existing pasture when there is more space between existing plants, and the choice of species increases. If the present vegetation is a sod with no space between plants, then it is advised to use a herbicide to kill the existing vegetation and then till prior to planting. Another option is to kill the existing vegetation and no-till plant into the dead sod, which will speed up establishment of the pasture. The cleaner the field without problem weeds when you plant, the longer the new stand will last.
- **Rodent control:** It is important to control rodents like pocket gophers, ground squirrels, and rock chucks because planting a new or renovating a new pasture is a long-term investment. If a pasture will continue to have problems with rodents such as pocket gophers, then it makes no sense to plant legumes, or forbs. These plants have taproots compared to a fibrous root system that grass species have. Rodents have a larger quantity and quality meal source with those large taproot plants and are often targeted first by the rodents.
- **Planting time:** Different grass, legume, and forb species can have different "best or specific times" to plant. They may have a broad range of time the seed can-be-planted in order to establish the field. If full-irrigation water is available, the best time to plant most perennial species for pastures and hay fields is the last

week of July / first week of August, because the plants develop a larger root and crown area over any other time of planting. This is because soil temperature is the warmest in the growing season with decreasing day-length. Most species can be planted spring through early fall. Elevation will control planting time in the late summer / early fall under irrigated conditions. The seed needs time to germinate and for the root systems of young seedlings to be established, a minimum of 6 weeks before the first killing frost in the fall is required. If irrigation water runs out in mid-summer, then spring planting is the only option. Dryland or rain-fed areas need to be planted in the fall, or frost seeded in the late winter / very early spring. There are a few species which do better if frost seeded.

- The following list is species adapted for pasture and hay in the Inland Pacific Northwest. The minimum precipitation needed for these species to produce is based mostly on sources east of the Rocky Mountains. Seed companies and University sources cited east of the Rocky Mountains are in a continental climate, not the Mediterranean climate of the PNW. This means less precipitation in the summer months for the Inland PNW compared with continental climate. When considering replanting a pasture, be sure to consider that the precipitation recommendations are utilized along with these other factors that will aid in selecting the appropriate species to plant.

Brief Descriptions of Pasture Grass Species Grown in the Inland Region

Note: The following list of species is a "readers digest version" of their attributes and most of the information is directly from the USDA NRCS plant fact sheet data base or other fact sheets. For more in-depth review of each species, go to the link listed at the end of each species; also go to the reference section for more information.

Bluegrass, Big (*Poa secunda*) is a native, perennial, long-lived, cool season bunchgrass that greens up before any other dryland grass species, up to 4 weeks earlier than crested wheatgrass. Big bluegrass is very palatable. It is excellent for early grazing in the spring in a dryland pasture system and can tolerate drought. It is not a deeply rooted grass and can spread with short rhizomes and seed shatter. It needs a minimum of 10 inches (254 mm) of annual precipitation, and yield will respond to higher precipitation. Unlike other bluegrasses, it will not tolerate heavy grazing, nor should it be grazed lower than 6 inches (15 cm) of stubble height, especially as it goes dormant.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_pose.pdf

Bluegrass, Kentucky (*Poa pratensis*) is a cool season, long-lived, rhizomatous, sod forming grass that is planted for pasture, or hay systems. It requires at least 18 inches (457 mm) of precipitation annually or irrigation to grow. It is highly palatable and is very tolerant of heavy and repeated grazing. Kentucky bluegrass is not as productive as other cool season grasses such as orchardgrass or tall fescue, but it does respond to nitrogen fertilizer and irrigation. Forage production is decreased in the warm or hot summer months. Whether the pasture is grazed properly or improperly, it will eventually become the dominant species in the pasture. If there are any bluegrass plants or seed left in the field when renovating a pasture or hay field the Kentucky bluegrass will eventually become the dominant species.

<http://www.speareseeds.ca/shared/media/editor/file/Hakari.pdf>

Brome, Alaska (*Bromus sitchensis*), (or Upland brome in New Zealand) is a short-lived, perennial, tall, erect, broad-leaved brome grass, similar to prairie grass. It is high yielding the first couple of years and palatable. For optimal production, it needs to be irrigated or grown in high precipitation areas. Every year or two it needs to set seed and reseed itself.

<http://www.speareseeds.ca/shared/media/editor/file/Hakari.pdf>

Brome, California (*Bromus carinatus*) is a cool season, native, annual, biennial, or short-lived perennial bunchgrass. It is high yielding the first few years, with yields diminishing over the following years. Length of stand can be variable. It has some drought tolerance and is palatable with good quality. It can be planted in mixtures or as a short rotation pasture or hay crop. Minimum annual precipitation needed is 8 inches (203 mm); it does better with 14 inches (356 mm). It responds very well to irrigation and nitrogen fertilizer. The NRCS plant guide recommends the different varieties that should be selected and planted, depending upon the MLRA in which it will be planted.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_brca5.pdf

Bromegrass, Downy (*Bromus tectorum*), also known as cheatgrass, is a winter annual grass that germinates in the fall, winter, and spring, and quickly goes to seed in the spring. It is an invasive weed and can quickly take over pastures that are overgrazed or mis-managed. It is drought tolerant and can be a nuisance in irrigated and dryland systems. It offers low yields and low quality, because uses most of its resources to put into seed production. It is very palatable and nutritious during a short period of time in the early spring before it goes to seed. It can be utilized by livestock and ungulates (deer,

elk, pronghorn, etc.) before forming seed and turning color, which makes it unpalatable. Fall rains can soften it up a bit, which can increase palatability.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_brte.pdf

Bromegrass, Grazing (*Bromus stamineus*) is a short-lived, moderately productive, cool season bunchgrass that is like prairiegrass, but the difference is grazing brome is finer leaved and more tolerant to grazing. It is not as productive as prairiegrass and requires 18 inches (457 mm) or greater of annual precipitation.

https://keys.lucidcentral.org/keys/v3/pastures/Html/Grazing_bromegrass.htm

Bromegrass, Hybrid (*Bromus inermis* x *Bromus biebersteinii*) is a cross between smooth bromegrass and meadow bromegrass. It is a long lived, cold hardy, perennial grass with less rhizomatous root spreading character than smooth bromegrass. It is high yielding (less than Meadow bromegrass, but more than smooth bromegrass) with very good quality and is palatable. Precipitation requirements would be similar to smooth and meadow brome, 12 to 16 inches (305 – 406 mm) of annual precipitation.

<https://peaceforagetool.ca/seed-infos.html?seed=6>

Bromegrass, Meadow (*Bromus biebersteinii*) is a long-lived, very winter hardy, cool season grass that has been selected for high yield, quality, and palatability. It requires at least a minimum of 14 - 16 inches (356 – 406 mm) of precipitation annually. It is competitive enough to thrive in a pasture mix, but it does not take over, or become as sod bound the same way as smooth brome does; it does have short, slow-growing rhizomes. Although it is a cool season grass; meadow brome is also known for producing growth during the hotter months of the year and can reduce the “summer slump” in a pasture, but does not produce as well as orchardgrass, tall fescue or reed canarygrass in the summer.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_brbi2.pdf

Bromegrass, Mountain (*Bromus marginatus*), is a native, short-lived, cool season grass that needs 16 - 18 inches (406 – 457 mm) of precipitation annually. It is tolerant of heavy grazing but is not very competitive. Mountain bromegrass tends to yield less and is lower in palatability and survivability than other perennial brome grasses. It is a good grass for a mix, or as a monoculture short term pasture or hay field for high yield production in the first two years.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_brma4.pdf

Bromegrass, Pasture (*Bromus valdivianus*) Pasture bromegrass is a moderately tillered, perennial brome grass species that is more persistent than prairiegrass under grazing. It provides strong spring–summer growth with drought tolerance, but only moderate winter growth. It is persistent on fertile, free-draining soils. Like other bromegrass species, it does not tolerate waterlogging or pugging, but it may tolerate higher rainfall conditions than other brome grasses. Unlike prairie grass, pasture bromegrass is resistant to head smut.

<https://barenbrug.com.au/forage-pasture/pasture-grasses/brome-grass>

Bromegrass, Prairiegrass (*Bromus willdenowii* Kunth syn: *B. catharticus* Vahl., syn *B. unioloides* H.B.K) is a short-lived, large seeded, bunchgrass that is of high quality and production the first two years of the stand. Stand longevity can be as short as 4 years, and therefore it is imperative to allow the plants to produce seed annually or every couple of years to allow reseeding of the stand. It can work well as a short-term hay field or in mixes to increase the first couple of years forage production. It is very quick to regrow once clipped or grazed. It needs to be grown under irrigated conditions or high rainfed conditions. <https://www.agricom.co.nz/management-advice/pasture-management/other-grasses/prairie-brome-management>

Bromegrass, Smooth (*Bromus inermis*) has been a common grass planted in pastures. It is a long-lived, very winter-hardy, cool season grass, which requires a range of 12 to 18 inches (305 – 457 mm) or more of precipitation to be fully productive but can survive with less. It is high yielding with excellent palatability and quality, with the greatest growth on the first harvest. Under higher precipitation, it is highly aggressive and can easily become the dominant species in a pasture mix. Smooth bromegrass has vigorous rhizomes and can become sod-bound without regular aeration. Smooth brome is slow to regrow after grazing or cutting.

https://plantsorig.sc.egov.usda.gov/factsheet/pdf/fs_brin2.pdf

Canarygrass, Reed (*Phalaris arundinacea*) is a rhizomatous, very aggressive sod forming, long lived, moderately palatable, cool season grass with great forage production potential. In the summer months with optimal irrigation water and fertilizer, no other cool season grass can produce as much forage. It needs a minimum of 16 inches (406 mm) of annual precipitation. It is one of the few grasses to develop aerial tillers. Selection of low alkaloid varieties is important because higher alkaloids are detrimental to livestock.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_phar3.pdf

Fescue, Hard (*Festuca brevipila*) is a long-lived, cool season, bunchgrass that is very hardy in cold dry climates that have marginal soils. It requires a minimum of 12 inches (305 mm) of precipitation annually. Hard fescue is recommended to stabilize erodible soils. It is early to produce new growth in the spring. It is less palatable than other dryland species but is more tolerant of grazing. However, grazing below 2 inches (5 cm) can severely damage the stand.

https://plantsorig.sc.egov.usda.gov/factsheet/pdf/fs_febr7.pdf

Fescue, Idaho (*Festuca idahoensis*) is a native, long-lived, drought tolerant, perennial, cool season bunchgrass. Palatability is good and yield is fair to moderate under dryland conditions. It needs a minimum of 12 to 14 inches (305 – 356 mm) of annual precipitation.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_feid.pdf

Fescue, Meadow (*Festuca pratensis*) is a short lived, perennial, cool season bunchgrass. It is very palatable with moderate yield potential for pasture. It does establish slowly and likes growing in moist sites. New varieties are being developed and it is also crossed with ryegrass species for developing new *Festulolium* variety species. It requires around 33 inches (838 mm) of precipitation or needs to be grown under irrigated conditions. <https://www.agproud.com/articles/32843-what-do-you-know-about-meadow-fescue-f>

Fescue, Mountain Rough (*Festuca campestris*) is a native, cool season bunchgrass. It is low yielding but has excellent forage quality and is palatable. It grows in areas with 15 to 24 inches (381 – 610 mm) of annual precipitation.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_feca4.pdf

Fescue Red (*Festuca rubra*) is a long-lived, cool season, native grass and there is a creeping red fescue grass; both have low growing habit, and the creeping type has rhizomes. It tolerates heavy grazing, but is not well suited for heavy traffic. Red fescue requires at least 15 - 18 inches (381 – 457 mm) of precipitation or more to survive. It is recommended for planting along roadsides, and areas, where groundcover is needed, but mowing or grazing is prohibitive. Utilizing red fescue, in a pasture, is not recommended, because of its low yields and poor palatability.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_feru2.pdf

Fescue, Sheep (*Festuca ovina*) is similar to hard fescue, as a cool season, long lived, drought and winter hardy, perennial bunchgrass with an excellent root system that makes it more drought tolerant than hard fescue. It is less palatable than other dryland species but is more tolerant of grazing. Grazing below 2 inches (5 cm) can severely damage the stand. It needs a minimum of 10 - 12 inches (254 – 305 mm) precipitation annually.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_feov.pdf

Fescue, Tall (*Lolium arundinaceum*) is a long-lived, cool season, perennial grass with short rhizomes, which produces high yields and quality forage. It is one of the most long-term responsive grass species to nitrogen fertilizer. It is adapted to a broader range of soil pH soils (acidic to saline) than most grasses and tolerates grazing and drought, as it is deep rooted. Tall fescue is recommended for irrigated pastures and hay fields, or fields that receive minimum of 16 to 18 inches (406 – 457 mm) of annual precipitation in a growing season. Palatability is not as good as other grass species, but newer varieties with softer, smoother leaves have much improved palatability. Tall fescue also begins growing earlier in the spring, grows very well and even produces in the hotter summer months. Tall fescue grows a little longer into the fall than most other grasses. It is one of the best irrigated pasture grasses for stockpiled forage - grazing for late fall through winter. Tall fescue can develop a symbiotic relationship with endophytes, which are a fungus that helps the plant thrive but is not healthy for livestock. The endophyte is introduced to the seed, and as it germinates, the plant becomes infected. When selecting a tall fescue variety, make sure it is “endophyte free”, or the infection rate is less than 15%. There are varieties with ‘novel’ or “friendly” endophytes, which do not harm livestock, which are also available for pasture and hay use.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_loar10.pdf

Fescue, Western (*Festuca occidentalis*) is a native, perennial, cool season, short-lived bunchgrass that is closely related to Idaho fescue. It is shallow rooted, though with some drought tolerance, producing low yielding, good quality forage. It has a short germination time. It needs a minimum of 14 inches (356 mm) of annual precipitation. <https://graniteseed.com/seed/grass-species/festuca-occidentalis/>

Festulolium (*festuca* spp. X *lolium* spp.) derives its name from a combination of *Festuca* (fescue genus) and *Lolium* (ryegrass genus). It is commonly a cross between meadow fescue or tall fescue and perennial ryegrass,

although other fescues and annual ryegrasses can be crossed. It offers high yields and quality under irrigated conditions, or areas that receive greater than 18 inches (457 mm) of precipitation. It is usually much more palatable, but less hardy, than tall fescue and may survive longer in a pasture system than perennial ryegrass; however, longevity of phenotypes can vary depending on species and varieties used as parents in the cross. For stand longevity, select varieties with more fescue genetics than ryegrass genetics. Diploids are better than tetraploids for ryegrass longevity genetics.

Foxtail, Creeping meadow (*Alopecurus arundinaceus*) is a perennial, winter hardy, long-lived, rhizomatous, sod-forming grass that likes wet meadows or irrigated land. It can handle flooding up to 45 days without killing it. It has a wide range of tolerating wet acidic to saline soils. It is moderately productive, very palatable, and produces high quality forage. It is an early heading grass, which continues to head out over time. It needs around 18 inches (457 mm) or more of annual precipitation, or irrigation.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_alar.pdf

Foxtail, Meadow (*Alopecurus pratensis*) is a perennial, cool season bunchgrass that can have short rhizomes. It is adapted to wet soil sites and to a range of acidic and salty soils but is less productive than Creeping meadow foxtail. It is a very palatable and high-quality grass. It needs a minimum of 12 inches (305 mm) of precipitation annually.

https://cascadiaprairieoak.org/wp-content/uploads/2019/09/Meadow-Foxtail_Management-Guide_CNLM_2019.pdf

Orchardgrass (*Dactylis glomerata*) is a long-lived, cool season, bunchgrass that has high yield potential, quality, and palatability. Orchardgrass tolerates moderate grazing and regrows quickly after harvest. It cannot tolerate grazing below 4 inches (10 cm). Orchardgrass requires at least 18 inches (457 mm) of precipitation annually. It grows best on a well-drained soil because it does not tolerate flooding for long periods. It is very responsive to nitrogen fertilizer and irrigation with high yield potential. ‘Paiute’ variety (selection from Potomac) does seem to survive and produce better than other varieties when irrigation water runs short during the season.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_dagl.pdf

Quackgrass (*Elytrigia repens*) is a rhizomatous, sod forming, long-lived grass. It has moderate yield and quality potential compared to many other grass species. Yield potential of quackgrass decreases in the warm

summer months. It is considered a weed but is fair to good forage. Quackgrass must be controlled before planting a new pasture or it will become the dominant species. <https://extension.usu.edu/rangeplants/grasses-and-grasslikes/quackgrass>

Ryegrass, Annual and Italian (*Lolium perenne*, ssp. *Multiflorum* Lam.) are annual grasses planted as a grazing cover crop, annual rotation crop, or with a perennial pasture system to aid in establishment. They germinate and establish very quickly, offering moderate yields, and high palatability, and quality while suppressing which suppresses weed competition and allows slower growing grasses to establish. Annual ryegrass is a weed in the eyes of grain growers and should be used with extreme caution or not at all around grain producers. If allowed to go to seed, it can become a nuisance. Italian ryegrass normally requires a vernalization period, meaning it must go through a winter season before it goes to seed. Often, annual ryegrass is sold as Italian ryegrass, or there is significant contamination in the seed. If you wish to avoid weedy annual ryegrass, make sure you are buying certified seed from a known Italian ryegrass source. There are also intermediate type ryegrass varieties (perennial x annual or Italian ryegrass). Tetraploid varieties are higher yielding in a short rotation but are not as long-lived or as hardy as a Diploid variety.

https://plantsorig.sc.egov.usda.gov/factsheet/pdf/fs_lopem2.pdf

Ryegrass, Perennial (*Lolium perenne*, ssp. *perenne*) is a short-lived, moderately yielding, cool season grass selected for very high quality and very high palatability. It is a quick germinating, very fast-growing bunchgrass that tolerates acidic soil pH. Perennial ryegrass requires at least 18 inches (457 mm) of precipitation or irrigation annually. It begins growth in the spring earlier than most irrigated pasture grasses. Because Perennial ryegrass is short lived and very desirable for livestock; it can be grazed out of a mixed pasture system within a few years. Some varieties have the highest carbohydrate and sugar concentration than any other grass species. This species is great for establishing a canopy early on for weed suppression while other grasses are slower to germinate establish in a mixed grass system. There are also intermediate type ryegrass varieties (perennial x annual or Italian ryegrass). Tetraploid varieties are higher yielding in a short rotation but are not as long-lived or as hardy as haploid varieties. *Epichloë festucae* var. *lolii* is the fungi that causes elevated ergovaline (lolitrem B) in perennial ryegrass varieties, which can cause 'ryegrass staggers'. Choose varieties with low or no added endophyte.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_lopep.pdf

Timothy (*Phleum pretense*) is a very long-lived, "annual with perennial habit", cool season bunchgrass that has very high yield potential producing high quality forage. It is very palatable; often elk will search out vegetative growth of timothy in the summer over alfalfa and other grasses. It is adapted to higher elevation and grows well in flooded systems. Timothy is very winter hardy. Timothy will not tolerate hot days for extended periods, and it has slight to moderate tolerance to drought, even though it is very shallow rooted. It requires at least 18 inches (457 mm) of precipitation annually, or more to produce optimally. Timothy will not tolerate heavy grazing and should only be harvested after it has regrown significantly to replenish its root and crown carbohydrate reserves. Timothy does tolerate Root lesion nematodes with no yield reduction, whereas many other grasses have no tolerance or resistance. It is a unique grass in that it forms 'corm' in the late summer/early Fall and creates new tillers for the following year's growth. These corms are carbohydrate and sugar storage banks. Maturity can vary 30 days between varieties.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_phpr3.pdf

Wheatgrass, Bluebunch (*Pseudoroegneria spicata*, ssp. *Spicata*) is a native, long-lived bunchgrass, which is utilized for its high quality and palatability. It has an extensive root system. Each variety is precipitation dependent, from 6 to 12 inches (152 – 305 mm) annually. It regrows quickly but cannot tolerate overgrazing or repeated grazing in a growing season. Because of its high palatability, Bluebunch wheatgrass can be grazed out early in a mixed grass species pasture.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_pssp6.pdf

Wheatgrass, Beardless Bluebunch (*Pseudoroegneria spicata* ssp. *Inermis*) is a cool season, drought tolerant, long-lived perennial bunchgrass. It starts growth early in the Spring. It is a short season growing grass with good palatability. It grows best with greater than 12 inches (305 mm) of annual precipitation.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_psspi.pdf

Wheatgrass, Crested (*Agropyron cristatum*, *Agropyron desertorum*, and *Agropyron cristatum*, x *desertorum*) is a long-lived, introduced, cool season grass adapted to areas that receive very little precipitation. Quality and production are generally higher in the first spring growth and then quickly decline. Crested wheatgrass has good palatability in the spring and can tolerate grazing, although overgrazing can be detrimental to the stand. It does not recover quickly after harvest. Palatability is low after the spring growth. It can be planted alone for easier grazing

management or can be planted in a mix of other drought tolerant plants that grow and produce more. Crested wheatgrass stops growing in the hotter weather.

“Standard or Fairway” crested wheatgrass (*Agropyron cristatum*) is not as drought tolerant as desert or Siberian wheatgrasses. They are adapted to the northwest and intermountain with at least 10 inches (254 mm) of annual precipitation. They do well on shallow to deep, moderately coarse to fine textured, moderately well to well drained and weakly acidic to moderately alkaline (saline and sodic) soils. Under alkaline conditions, vigor and production are reduced. The Fairway type was first recognized in 1950 as being different compared to other crested types. Fairway is shorter, denser, finer stemmed, and less productive than desert wheatgrass at lower elevations, but may exceed desert wheatgrass production at higher elevations.

“Desert” crested wheatgrass (*Agropyron desertorum*) is more drought tolerant than cristatum or fairway wheatgrass. It is not as drought tolerant as the Siberian type. Desert wheatgrass is adapted to the Northwest and Intermountain regions with at least 8 inches (203 mm) of annual precipitation below 6500 feet (1981 m) elevation. It does well on shallow to deep, moderately coarse to fine textured, moderately well to well drained and weakly acidic to moderately alkaline soils. Under saline conditions vigor and production are reduced. It is considered slightly more saline tolerant and more productive than fairway wheatgrass.

“Hybrid” crested wheatgrass (*Agropyron cristatum* × *Agropyron desertorum*) is a hybrid cross, which results in a plant with excellent seedling vigor. The following cultivars are hybrid crosses and considered similar to desert wheatgrass: ‘Hycrest’ and ‘CD-II’. CD-II is a selection of Hycrest and was released to ensure the genetic purity of the cross. It has increased growth characteristics under cold temperatures. Characteristics and performance are the same as Hycrest. Hycrest is easier to establish than either of its parents (fairway and desert wheatgrass), and is more productive during the establishment period than either parent. Long-term productivity exceeds Fairway and it is equal to the desert wheatgrass. The leaves and stems are coarser, and it has more stems than Fairway types. Good stands have been established in the 8 inch (203 mm) or greater precipitation zones. It is best adapted to 5,000 - 9,000 feet (1524 – 2743 m) elevation zones, but good stands are common to 2,500 feet (760 m). It does well on all soil types. Under slightly saline conditions, vigor and production are reduced. It is not adapted to excessively saline areas.

https://plants.usda.gov/DocumentLibrary/factsheet/pdf/fs_agcr.pdf

Wheatgrass, Intermediate (*Thinopyrum intermedium*) a long-lived, moderately drought tolerant, rhizomatous,

later maturing, cool season perennial grass that has moderately high yields and good quality. It requires a minimum range of 12 - 14 inches (305 – 356 mm) of precipitation, but 15 - 18 inches (381 – 457 mm) or greater precipitation annually for full production. It is one of the higher forage producing species under dryland conditions and has good palatability. It has a quick developing root system that works great for establishment in soils that need stabilization. It is critical that intermediate wheatgrass not be overgrazed and is allowed to rest after harvest.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_thin6.pdf

Wheatgrass, Pubescent (*Thinopyrum intermedium* spp. *barbulatum*) is a drought tolerant, rhizomatous, sod forming, long-lived, cool season grass with slightly more winter hardiness and drought tolerance than intermediate wheatgrass. The minimum range of precipitation is 11 - 13 inches (279 – 330 mm) annually. It has an excellent root system and tolerates some level of alkaline soils. It has good palatability.

https://plantsorig.sc.egov.usda.gov/factsheet/pdf/fs_thin6.pdf

Wheatgrass, RS Hybrid (*Elymus hoffmanii*) is described as a “long-lived”, sod forming with weak rhizomes, cool season, perennial grass. It is a cross between Bluebunch wheatgrass (*Pseudoroegneria spicata*, ssp. *Spicata*) and Quackgrass (*Elytrigia repens*). It needs 12 - 14 inches (305 – 356 mm) of annual precipitation. It is very palatable, producing high quality forage and has the same alkaline tolerance as Tall wheatgrass. It does not survive in a 10 inch (254 mm) average precipitation zone, nor has it persisted in irrigated trials (non-saline soils) in Central Oregon and Washington.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_elho3.pdf

Wheatgrass, Siberian (*Agropyron fragillie*) is a long-lived, introduced bunchgrass that is very drought tolerant and can survive and produce with as little as 7 to 8 inches (178 – 203 mm) of precipitation annually; so it is more drought tolerant than any of the Crested wheatgrass varieties. It can grow up to 7,000 feet (2,134 m) in elevation. It is most productive in the spring and early summer, and generally more adapted to saline soils than Crested wheatgrass. This grass has finer leaves and will stay greener longer in the summer than Crested wheatgrass. Siberian wheatgrass does not tolerate overgrazing, and at least 3 inches (7.5 cm) of stubble height should remain at the end of the grazing season for Siberian wheatgrass to survive through the winter. ‘P27’, ‘Vavilov’, and ‘Vavilov II’ are Siberian wheatgrass varieties. P27 has poorer seedling vigor than Vavilov.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_agfr.pdf

Wheatgrass, Slender (*Elymus trachycaulus* spp. *Trachycaulus*) is a perennial, palatable, cool season bunchgrass that does have short rhizomes. Varietal difference includes tolerance from acidic to saline, or salty soils, and drought tolerance, along with different forage yield potential. It is a short-lived species, but some varieties can persist 5 to 10 years. It germinates and establishes quickly across different landscapes and soils. It needs a minimum of 10 inches (254 mm) of annual precipitation.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_eltr7.pdf

Wheatgrass, Snake River (*Elymus wawawaiensis*) is a native, cool season, long-lived bunchgrass that is adapted to regions that receive little precipitation. It can survive in areas that receive as little as 8 inches (203 mm) of precipitation. It is more vigorous than other natives such as bluebunch wheatgrass and matures early in the season.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_elwa2.pdf

Wheatgrass, Streambank (*Elymus lanceolatus* ssp. *Psammophilus*) is a very drought tolerant, rhizomatous, sod forming, and perennial, cool season grass species. It is less palatable compared to Thickspike wheatgrass, of which it is closely related. It needs a minimum of 6 - 8 inches (152 - 203 mm) of annual precipitation.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_ellal.pdf

Wheatgrass, Tall (*Thinopyrum ponticum*) is a long-lived, tall, slow maturing, moderately drought tolerant bunchgrass adapted to produce high yields on marginal areas such as alkaline or saline soils. It works best in areas with 12 - 14 inches (305 - 356 mm) of annual precipitation. It is one of the most tolerant of growing in saline/alkaline soils. Because of its slow maturity, it remains productive and has better palatability than other cool season grasses later into the year. Palatability is low after it goes to seed. Tall wheatgrass does not tolerate heavy grazing, and sufficient stubble height must remain in the fall for the plant to recover properly the following year. Tall wheatgrass can be planted in single rows every 45 - 60 feet (1,372 - 1,829 cm) apart as wind breaks in dryland hay or pasture fields to trap snow for increased snow capture and moisture retention.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_thpo7.pdf

Wheatgrass, Thickspike (*Elymus lanceolatus* ssp. *lanceolatus*) is a rhizomatous, sod forming, very drought tolerant, long-lived cool season grass. It resembles

western wheatgrass but can head out 3 weeks earlier. Palatability is good throughout the year. It needs a minimum of 6 - 8 inches (152 - 203 mm) of annual precipitation.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_ella3.pdf

Wheatgrass, Western (*Pascopyrum smithii*) is a native, cool season, rhizomatous grass that is long lived, late maturing, and creates a healthy sod. It is used for stabilization or reclamation, but it is also a great plant for pasture systems. It is a high yielding, high quality grass that can produce forage in the range of 12 - 20 inches (305 - 508 mm) of annual precipitation. If Western wheatgrass receives more than 20 inches (508 mm) of precipitation, it can become very aggressive and quickly overtake the entire pasture. Western wheatgrass decreases in palatability as it matures in the hotter months of the year.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_pasm.pdf

Wildrye, Altai (*Leymus angustus*) is a long-lived, perennial, cool season, winter hardy, bunchgrass that has short creeping rhizomes. It is very deep-rooted and is very drought, alkaline and salt tolerant. It produces excellent forage during the growing season, and stockpiles well for winter grazing. It requires a minimum of 14 inches (356 mm) of precipitation.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_lean3.pdf

Wildrye, Basin (*Leymus cinereus*) is a native, long-lived, tall, cool season bunchgrass that is very high yielding under dryland conditions. Established stands are very productive. It is very palatable in the spring but decreases in palatability and quality as it matures. It can provide winter grazing under snow covered pasture conditions because of its height. It is adapted for areas that receive as little as 8 inches (203 mm) of precipitation. It has low seedling vigor and can be difficult to establish. It should not be grazed until the end of the second growing season.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_leci4.pdf

Wildrye, Beardless (*Leymus triticoides*) is a native, long-lived, cool season, rhizomatous grass that is utilized for its ability to stabilize otherwise marginal soils, such as high alkaline or saline/sodic soils. It is adapted to dryland areas that receive as little as 8 inches (203 mm) of rainfall a year. It forms a thick sod that helps in its stabilization abilities. Beardless wildrye is a very slow germinator and difficult to establish. It does not compete well during establishment. It can tolerate prolonged flooding and does produce good forage for grazing or hay.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_letr5.pdf

Wildrye, Canadian (*Elymus Canadensis*) is a short-lived, tall, perennial, cool season bunchgrass that is a quick germinating and establishing grass. It likes moist sites and has good palatability in the spring, but it is not grazing tolerant. It needs a minimum of 12 inches (305 mm) of annual precipitation.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_elca4.pdf

Wildrye, Dahurian (*Elymus dahuricus*) is a short lived, perennial, cool season bunchgrass. It is a very palatable forage producer with high quality. It is a quick establishing grass and recovers quickly from haying or grazing. It is usually used in grass mixes for earlier forage production until later maturing species can establish. It is also used for a short crop rotation for hay and pasture. It needs a minimum of 12 inches (305 mm) of annual precipitation.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_elda3.pdf

Wildrye, Mammoth (*Elymus racemosus* spp. *Racemosus*) is a long-lived, rhizomatous, sod forming, perennial, winter hardy, cool season, grass. Mammoth wildrye has poor to fair palatability; it is not recommended for planting as a forage crop. It is very drought tolerant, capable of growing with as little as 7 inches (178 mm) of annual precipitation.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_lera5.pdf

Wildrye, Russian (*Psathyrostachys juncea*) is a long-lived, cold- and drought-hardy, cool season bunchgrass that is adapted to dryland pasture settings that receive as little as 8 inches (203 mm) of annual precipitation. It has an incredible horizontal root system. The grass greens up earlier in the spring than Crested or Siberian wheatgrass, but not as early as Big bluegrass. It has rapid regrowth and high palatability. It retains its quality like most wildryes later into the growing season and stockpiles well into winter compared to other grasses. It does tolerate heavy grazing and it is slow to establish in a grazing system. It can be planted in a mix with other species such as Crested or Siberian wheatgrass to extend the growing season from early spring to summer.

https://plantsorig.sc.egov.usda.gov/plantguide/pdf/pg_psj3.pdf

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Appendix Chapter 4b

Legumes and Forbs for the Dryland and Irrigated PNW

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Note: The following list of species is a “readers digest version” of their attributes and most of the information is directly from the USDA NRCS plant fact sheet data base. For more in-depth review of each species, go to the link listed at the end of each species; also go to the reference section for more information.

Legumes

Alfalfa (*Medicago sativa*), is an introduced, moderate to long-lived perennial legume. Flowers can vary in color from purple to yellow, borne in loose clusters. Alfalfa's stems are erect and grow from a woody crown to about 2 to 3 feet (60 – 90 cm) tall. Most alfalfa varieties have a taproot, and hosts rhizobia bacteria which fix nitrogen. Its roots can penetrate many feet into the soil. There are other varieties of alfalfa with branched or creeping type root systems. Leaves are alternately arranged on the stem, and are normally trifoliate, but some varieties can be multi-foliate. Alfalfa grows best on deep, well-drained, friable soils. It does not tolerate flooding. The pH of the soil should be 6.5 or above, but there are varieties that will tolerate higher pH and saltier soils. Alfalfa is a bloating legume. Minimum annual precipitation needed for alfalfa is around 10 to 12 inches (254 – 305 mm) and does have excellent drought tolerance. There are numerous varieties available for planting in irrigated fields. Selection of variety should be made based on conventional, hybrid, or Roundup Ready genetics desired, along with fall dormancy, winter survival index, salt tolerance, grazing tolerance, precipitation or irrigation, and pests (insects, nematodes, diseases) ratings. See <https://www.alfalfa.org/varietyLeaflet.php> for available varieties under all conditions. Varieties for dryland plantings might include ‘Melton’, ‘Shaw’, ‘Ladak II’, ‘Ladak +’ ‘Big Sky Ladak’, ‘Rugged’, ‘Ranger II’, ‘Ladak 65’, and ‘Ladak’. https://plants.sc.egov.usda.gov/DocumentLibrary/fact-sheet/pdf/fs_mesa.pdf

Alfalfa, Yellow-flowered or Falcata (*Medicago sativa* subsp. *falcata*) is an introduced perennial, forage legume.

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It has trifoliate leaves, multiple stems, and a thick, somewhat woody crown. It's roots host nitrogen-fixing bacteria. Yellow flowered alfalfa roots are more branching and fibrous than the tap-root of purple-flowered alfalfa. Yellow-flowered alfalfa may be cultivated in monoculture or inter-seeded with shrubs or grasses and/or with purple-flowered alfalfa. Yellow-flowered alfalfa is best adapted to medium textured soil with a pH between 6 and 8. It does well in areas with low precipitation and cold winters. Yellow-flowered alfalfa is used for dry hay, green chop, silage, and grazing and has a potential as a summer-stockpiled forage. It is a source of nectar and pollen for pollinator insects and provides habitat for birds and mammals. Yellow-flowered alfalfa exhibits an indeterminate flowering habit and works well for dryland pastures; Quality does not decline as much as purple flowered alfalfa as the plant matures. Current cultivars available as of 2020 are ‘Don’ and ‘Sholty’ in the U.S., and ‘Anik’, and ‘AC Yellowhead’ in Canada.

https://plants.sc.egov.usda.gov/DocumentLibrary/plant-guide/pdf/pg_mesaf.pdf

Clover, Kura (*Trifolium ambiguum*) is an introduced, perennial. It has a prostrate, rhizomatous growth habit and attains a maximum height of 1 foot (30 cm). The leaves are composed of three leaflets, which have a “crescent” or “water mark” on the upper surface. The leaves have prominent veins, sawtooth margins, and a smooth stalk. The round flower heads have 40 to 100 florets and are borne on stalks from the leaf axils. Florets are white to pink and have smooth stalks.

Kura clover thrives best in a cool, moist climate. In general, Kura clover is best adapted to clay and silt soils in humid and irrigated areas. It grows well on droughty soil but does not tolerate poor drainage. Kura clover's dense rhizomatous root system penetrates the soil to a depth of 2 feet (60 cm). Kura clover is slow to germinate, has poor seedling vigor, and does not establish a solid stand in the first year. A more reliable establishment will be with new plantings. Broadcast plantings are not recommended. Kura clover has the potential to be an important pasture legume. It is highly palatable, and a nutritious forage for all classes of livestock. Kura clover is not recommended for hay or silage. Kura clover can be grazed to a stubble height of 2 inches (5 cm) with rest intervals between three and five weeks. Yields vary from 2.5 - 4.5 tons per acre (5.5 – 9.9 Mg/ha). Cultivars include ‘Rhizo’, ‘Endura’ and ‘Cossack’, bred for rapid establishment and higher yields. <https://www.nrcs.usda.gov/plantmaterials/wvpmcpg7040.pdf>

Clover, Alsike (*Trifolium hybridum*) is an introduced, short-lived, non-creeping perennial with a growth habit similar to red clover. It can be distinguished from red clover by the absence of crescent-shaped marks on each leaflet and more conspicuously toothed leaves. Tillers grow profusely from the crown. Stems are semi-erect, long, thin, smooth, and usually hollow with very short, almost spherical axillary racemes about 0.75 to 1.4 inches (2 - 3.5 cm) in diameter. Each raceme has about 30-50 white or pale pink flowers. Alsike clover has a branched tap root. Alsike clover reaches a height of 2 to 4 feet (60 – 120 cm). This introduced plant tends to recline or lodge unless companion plants help hold the stem upright.

Alsike clover is used for hay, pasture, and soil improvement, and adapted to a wide range of soil types and grows well in northern latitudes and at high elevations. It survives severe winters and performs best where summers are cool. It grows well on soils that are too acidic for red clover (pH < 6.0) and can tolerate more alkalinity than most clovers. It will tolerate wetter soils better than other clovers. It prefers silty clay loams where moisture is sufficient throughout the growing season with mean annual precipitation of 18 inches (457 mm) or more. Alsike clover does not tolerate drought, but will tolerate soils that are completely waterlogged, and will withstand spring flooding up to 6 weeks. It is not shade tolerant. Alsike clover is usually planted with grasses for pasture and hay in areas where other higher yielding legumes are not adapted.

Although alsike clover is lower yielding than red clover, it withstands excessive soil moisture and is more tolerant of acid soils. Mixtures of alsike and red clover ensure some clover is present if the red clover fails to establish on water-logged and/or low pH areas within a field. Alsike and red clover mixtures will produce more hay combined, than when planted separately. Avoid planting alsike clover with tall-statured grasses as it is not tolerant of shade. Grasses minimize the lodging of alsike clover by helping to keep it upright.

Close grazing, e.g., 2 inch (5 cm) stubble height favors this clover, whereas light grazing favors grass. Pastures should be rotationally grazed. Alsike clover causes bloat and should be fed to livestock with care. It has also been implicated as causing “alsike clover poisoning” in horses. Alsike-induced photosensitization has been reported among animals grazing alsike clover.

Cultivars of alsike clover are either diploid or tetraploid types. The cultivars used in North America are diploid. Most of the seed available in the United States is common seed. Canada has improved cultivars: ‘Aurora’ (1961); ‘Dawn’ (1974) Several cultivars have been developed in Denmark, Norway and Sweden, but are not available or used in the United States to any extent.

https://plants.sc.egov.usda.gov/DocumentLibrary/plant-guide/pdf/pg_trhy.pdf

Clover, Western prairie (*Dalea ornata*) is a perennial, herbaceous, native legume that grows to 12 to 24-inches (30.5 – 60 cm) in height. It has a cluster of stems that arise from a taproot. Leaves are 1.6 to 2 inches (4.1 – 5 cm) long, alternate, and odd pinnate, comprised of 5 – 7 oval shaped leaflets, each 0.4 – 0.8 inch (1 – 2 cm) long. Flowers occur in dense, cylinder-shaped spikes. The flowers are light pink to purple in color and have 5 petals. The flowers bloom upward along the spike in May – July.

Western prairie clover is native to southeastern Washington, western Idaho, eastern Oregon, northern California and northwestern Nevada. It is adapted to low to moderate elevations, and soft clay and sandy soils. Western prairie clover is used in seeding mixes for diversification and revegetation of pastures and rangelands. It is a non-toxic legume and has the potential for increasing forage production and quality. To improve the plant’s ability to establish and fix nitrogen, the seed should be inoculated with the proper *Rhizobium* bacteria strain prior to planting. Weeds must be managed for several years to ensure successful establishment. This plant does not appear to spread aggressively by seed or vegetative means. The plants continue to flower while seed produced earlier in the season matures. There are no commercially available cultivars. https://plants.sc.egov.usda.gov/DocumentLibrary/plantguide/pdf/pg_daor2.pdf

Clover, Strawberry (*Trifolium fragiferum*) is an introduced, perennial, low-growing plant with creeping stems that root at the node (stolons) to spread. It is sub-glabrous with slender, pointed trifoliate leaves. Seedlings are initially tap-rooted and then stolons initiate from leaf axils to form a prostrate plant network. The inflorescence is globular and compact, with pink or purplish red florets. Strawberry clover resembles white clover in stature.

Strawberry clover can establish and persist on wet saline and alkaline soils and is adapted to wet meadows, streams and seeps. It is the most saline tolerant clover commercially available. Strawberry clover withstands flooding because the stolons have a tropic response that causes the tips to be elevated above the water level. It is adapted to a wide range of soil textures from loam to clay and tolerates soil pH of 5.3 - 8.2. It is tolerant of flooding for up to 2 months, salinity (up to 3% concentration), and short-term drought. It needs at least 25 inches (635 mm) of annual precipitation to thrive but can withstand mean annual precipitation as low as 17 inches (432 mm). Strawberry clover is hardier and more tolerant of harsh environmental conditions than white clover.

Strawberry clover is mainly used for pasture. Strawberry clover seedlings are easily established and grow rapidly. Strawberry clover spreads primarily by stolons and to a lesser degree by seed and can spread into adjoining vegetative communities under ideal climatic and environmental conditions. Established stands improve over time. Strawberry clover is tolerant of grazing once the plants have developed strong stolons or runners. It should not be grazed lower than 2 to 4 inches (5 – 10 cm) to reduce shading by grasses so that strawberry clover persists. The minimum plant height to begin grazing for most clovers is 4 inches (10 cm). The minimum stubble height to remain at end of grazing is 3 inches (7.5 cm). Strawberry clover can cause bloat in ruminants and increase the incidence of urinary calculi in sheep. These problems can be managed by maintaining a significant component of grass in the pasture.

Some cultivars include 'Fresa', 'Salina', 'Palestine', 'Prinsep Park', 'O' Connors', 'Grasslands Onward' and 'Grasslands Upward'. [/https://plants.sc.egov.usda.gov/DocumentLibrary/plantguide/pdf/pg_trfr2.pdf](https://plants.sc.egov.usda.gov/DocumentLibrary/plantguide/pdf/pg_trfr2.pdf)

Sweetclover, Yellow and White blossom

(*Melilotus officinalis*, *M. alba*) are an annual to biennial forb reaching 5 feet (1.5 m) in height. Leaves are trifoliolate (3 leaflets) with short stems. Flower stalks bear 20 to 65 flowers. Yellow blossom sweetclover is shorter growing, more widely branching, finer stemmed, more drought tolerant, and easier to establish than white sweetclover. Like other plants in the legume family, sweetclover forms root nodules when infected with the correct rhizobium bacteria, and fixes nitrogen. Seed in the soil can remain viable for 40 or more years. Sweetclover plants will grow in low to middle elevations, from sea level to 8,500 feet (2,591 m). It is planted extensively for rangeland plantings, soil stabilization, and reclamation projects as well as for pasture.

Sweetclover is the most drought tolerant of the commercially available legumes. It has been used effectively in areas receiving as little as nine inches mean annual precipitation, though it does best in 12 to 20 inches (305 – 508 mm) precipitation zones. Sweetclover commonly establishes from seed during years with abundant spring rains and remains in the plant community for at least two growing seasons. Then during periods of drought, it will lay dormant, until another good moisture year occurs, and it becomes abundant once again. Sweetclover seedlings can tolerate 10 to 14 days of early spring flooding. Yellow and white sweetclover are adapted to all soil textures, but they perform best on medium textured sandy to clayey soils. Sweetclover will not tolerate acidic soils; a pH of 5.5 is the plant's lowest limit. It can however withstand slight to moderate saline conditions. Sweetclover is highly tolerant of frost and cold temperatures. The plants have evolved contractile roots, which pull the plant crown

down into the soil in the fall, allowing the plant to survive cold winter temperatures. Sweetclover is not shade tolerant.

It is less palatable than many other legumes because of its bitter taste caused by the chemical coumarin in the plant tissue. Coumarin is the cause of sweetclover bleeding disease, which affects cattle after prolonged grazing on moldy or damaged sweetclover hay. Cattle graze it sparingly at first but increase intake as they become used to the bitter taste. It is somewhat more palatable in spring and early summer than later in the season when stems become woody. It has fair to good palatability for cattle, sheep, and horses. Bloat caused by sweetclover is less of a problem than with alfalfa and clover species. Sweetclover has been used to improve forage production for livestock on low forage value sites. Sweetclover hay yields are good, but it can be difficult to harvest.

Sweetclover has rapid growth, easy establishment and increases nitrogen in poor soils. The large taproot increases aeration and water absorption by opening the subsoil. Establishing stands should not be grazed during the year of establishment. Begin grazing the second year when new growth is 6 to 8 inches (15 – 20 cm) tall.

It is recommended to not feed sweetclover to livestock for at least three weeks prior to castrating or dehorning and 30 days prior to calving. Sheep and horses are less prone to sweetclover bleeding disease due to their more selective eating habits. The best way to avoid sweetclover "bleeding disease" is to use certified seed of low-coumarin varieties such as 'Norgold' or 'Polara'. Some Yellow blossom sweetclover varieties are 'Goldtop', 'Madrid', 'Norgold' and 'Yukon'. 'Evergreen' and 'Polara' are releases of white sweetclover. https://plantsorig.sc.egov.usda.gov/plantguide/doc/pg_meof.docx

Clover, White (*Trifolium repens*) is a perennial introduced legume and has become one of the most widely distributed legumes in the world. It generally has a prostrate, stoloniferous growth habit. The leaves are composed of three leaflets, which may or may not have a "crescent" or "water mark" on the upper surface. Leaves and roots develop along stolons at nodes. Florets are white but may have a pink hue.

White clover thrives best in a cool, moist climate and is best adapted to clay and silt soils in humid and irrigated areas. It grows successfully on sandy soils with a high-water table or irrigated droughty soils when adequately fertilized. White clover seldom roots deeper than 2 feet (60 cm), which makes it adapted to shallow soils when adequate moisture is available. Dry soils limit establishment and persistence of white clover. Lack of winter hardiness limits the use of white clover in areas that have cold winters and lack of snow cover.

White clover is normally used as a companion crop with forage grasses to provide a source of nitrogen while also providing high yielding, high quality forage. It is a

palatable and nutritious forage for all classes of livestock and wildlife. White clover has medium to high bloat potential when grazed. The three general types of white clover cultivars are (1) large, (2) intermediate, and (3) small.

Large type is often called the Ladino type, which grows tall enough to be harvested for hay, silage, and green chop. Clover in general is more difficult to put up as hay. It is two to four times as large as common white clover. It will winter kill under dry winter conditions. Intermediate type white clover would be the New Zealand and Dutch white clovers. Small type is the wild white types adapted to higher elevations and colder areas. It is the most drought-resistant type. It is very persistent in pastures, withstands close grazing, but is the least productive of the white clovers. There are many varieties available of each type. https://plants.sc.egov.usda.gov/DocumentLibrary/plantguide/pdf/pg_trre3.pdf

Crownvetch (*Coronilla varia*) is an herbaceous, perennial legume introduced from the Mediterranean region. Leaves are dark green and pinnately compound, usually with 15 ovate-oblong leaflets. It has coarse, strongly branched stems that are 2 to 6 feet (60 – 180 cm) long and upright to trailing. Crownvetch has a multi-branched root system and spreads by strong fleshy rhizomes. Flowers are pinkish-white to deep pink in long-stalked clusters. It is not a true vetch and does not have tendrils for climbing. It normally grows to a height of 1.5 to 2 feet (45 – 60 cm). Crownvetch has a broad adaptation to soil texture. It does well on sand, gravelly-rocky soils, loams, and clays. It will grow on low fertility sites and on acid soils with a pH of 5.0 to 5.5, but it is not very tolerant of salt and alkali. Crownvetch requires good moisture, at least for part of the growing season. Established crownvetch will withstand long periods of drought. It should be planted in areas with 18 inches (457 mm) or more annual precipitation or where supplemental irrigation is provided. Crownvetch is cold-tolerant; however young seedlings will winter kill, so plants should be well established before fall. Crownvetch spreading growth habit and strong root system provide soil holding ability and ground cover. Crownvetch produces palatable high quality forage. There is little or no bloat hazard in grazing crownvetch. For best results, seeds should be inoculated with the appropriate legume bacteria before planting.

Normally, crownvetch will not make sufficient growth for use in the first year. First hay harvest should be about 10 to 14 days after first flowers appear and leave a 6 inch (15 cm) stubble as new growth will come from buds on the stems. The second harvest will come about 8 to 9 weeks later. Drying the hay may be more of a problem than with other legumes. Begin grazing about the same time as cutting for hay. Recovery may be more rapid after grazing than after hay cutting as livestock will eat the leaves and let

the long stems remain. New growth will initiate from the many buds on the stems. Rotate grazing, and then regraze after 10 to 14 inches (25 – 35 cm) of growth is made. Mature crownvetch is a little more palatable than most other legumes, therefore it can be stockpiled to take advantage of other forages, but nutritional value decreases with maturity. Cultivars available include ‘Chemung’, ‘Emerald’, and ‘Penngift’. https://plants.sc.egov.usda.gov/DocumentLibrary/factsheet/pdf/fs_cova2.pdf

Lupin, Russell (*Lupinus polyphyllus* x *L. arboreus*) can be a long lived legume and is used for grazing in New Zealand and Australia. This lupin is considered a poisonous landscape garden plant, but, “Sweet” varieties have been developed in Russia, Finland, and New Zealand that have lower alkaloids and are mixed with grass species for pasture. The plants are tolerant to acidic high aluminum soils and have a deep taproot. Producers are getting excellent gains on lambs in rain-fed pastures 24 inches (610 mm) precipitation zone of New Zealand. This plant, if possibly to include in pastures in the future, needs to be investigated and researched more for the PNW, as it can become an aggressive weed, spreading by seed. file:///C:/Users/bohlem/Downloads/https_www.grassland.org.nz_publications_nzgrassland_publication_1026.pdf

Milkvetch, Cicer (*Astragalus cicer*) is a very long-lived, introduced perennial, non-bloating legume with vigorous creeping roots or rhizomes. Stems are large and hollow, upright when young and becoming decumbent and trailing. Stems can reach to 10 feet (300 cm) in length in one season. Young plants may reach heights of 3 feet (90 cm), but older plants become more trailing in nature. Leaves are 4 to 8 inches (10 – 20 cm) long with 10 to 13 pairs of leaflets, plus one terminal leaflet. Leaves are ¾ - 2.5 inches (1.9 – 6.2 cm) long. Flowers are pale yellow to white with 15 to 60 flowers growing in a compact raceme. The species has a very wide range of adaptation.

Cicer milkvetch will grow in soils of all textures from clays to sands, but best performance comes from plants grown on moderately coarse textured soils. Plants are adapted to slightly acidic to alkaline soils with pH levels of 6.0 to 8.1. The species is moderately salt tolerant. These plants also do well on poor, disturbed soils making it useful for critical area plantings.

Cicer milkvetch produces best on 18 to 35 inches (457 – 889 mm) of moisture annually, but the species also exhibits good drought tolerance and has been established on dryland sites in areas receiving as little as 14 inches (356 mm) mean annual precipitation. It is recommended for use in regions receiving greater than 15 inches (381 mm) annual precipitation. Cicer milkvetch also does well on wet sites or on sub-irrigated sites where ground water is within 3 feet (90 cm) of the soil surface.

Hardy underground root crowns and prolific rhizomes prevent plants from being severely damaged by frost. The plants require only 30 days of frost-free growth per season, and grows at elevations up to 7,000 feet (2134 m). Cicer milkvetch has many qualities that make it a viable choice as a non-bloating legume for hay or pasture. The high protein content of cicer milkvetch is due, in part, to the high leaf to stem ratio and ability to retain leaves during drying and baling. It retains leaves longer in the season than alfalfa, birdsfoot trefoil or sainfoin, which equates to higher in vitro dry matter digestibility. No bloating has been reported from grazing cicer milkvetch. Stands of cicer milkvetch resist overgrazing because of its vigorous sod forming rhizomes. Recovery from grazing is rapid, but recovery after cutting hay is relatively slow. Close grazing stimulates growth from the base of lower leaves, crowns, and rhizome buds. This results in increased stand density following grazing.

Its extensive and prolific root system holds soil and provides quick recovery and rapid growth in area plantings. Its nitrogen fixing ability also provides nitrogen to other species planted in mixtures. Emergence occurs 10 to 14 days after planting as compared to 7 to 10 days for alfalfa. Seedling vigor is good, and the growth rate of cicer milkvetch exceeds that of alfalfa as temperatures increase in summer. Cicer milkvetch stands normally improve with age due to the proliferation of plants via rhizomes. Leaves and stems stay green and succulent later into fall and stockpiles well even under snow, compared to alfalfa. Spring growth starts 14 to 28 days later than alfalfa and growth increases with rising temperatures. The best way to establish cicer milkvetch is to plant grass and the cicer milkvetch in alternate rows, which allows better establishment of cicer milkvetch.

Some cultivars available are 'Lutana', 'Monarch' 'Windsor', 'HiPal', 'AC Oxley,' and 'AC Oxley II' (improved seedling vigor and yield) https://plants.sc.egov.usda.gov/DocumentLibrary/plantguide/pdf/pg_asci4.pdf

Milkvetch Canadian (*Astragalus canadensis*) is a native, short-lived perennial, rhizomatous legume that grows with smooth, stout stems, up to 5 feet (152 cm) tall. The leaves are smooth; elliptic to oblong, with thirteen to thirty-one stalked leaflets that are 1 to 2 inches (2.5 – 5 cm) long. The flowers are greenish white to cream colored, with a regular pea flower shape, located at the ends of long stalks. Canadian milkvetch is commonly found in somewhat dry prairies, moist shores, riverbanks, marshy grounds and open or partly shaded ground. This species requires a well-drained soil in a sunny position. It has low tolerance of root disturbance and cannot tolerate extremely cold weather. It is a very palatable forage. Germination can be slow, four to nine weeks. *Canadian milkvetch looks similar to some closely related poisonous locoweeds, so its use is not recommended, unless positive identification can be made.*

Many members of this genus contain a poison that affects cattle. They become affected with a slow poisoning that can cause death within a period of months, or even take a year or two. There are no cultivars, only land race types, and seed can be very expensive. Minimum annual precipitation needed is around 13 inches (330 mm). https://plants.sc.egov.usda.gov/DocumentLibrary/plantguide/pdf/pg_asca11.pdf

Sweetvetch, Utah (*Hedysarum boreale*) is a native perennial, cool season, herbaceous legume with deep taproots and several lateral roots. The main stems arise from a woody crown and may grow 1 to 2 feet tall (30 – 60 cm). The leaves are compound and flowers can be pink, purple, or white arranged in a loose raceme. Utah sweetvetch can grow on clayey or sandy soils, however, is more adaptable to well-drained, loamy soils. It is most often found on moderately saline or alkaline soils but will grow on moderately acidic to neutral soils. Utah sweetvetch is found at elevations between 4,000 - 8,000 feet (1,219 – 2,428 m), in precipitation zones receiving 10 - 18 inches (25 – 45 cm) of moisture annually. It grows better with 15 inches (381 mm) or more of precipitation and minimal competition.

Utah sweetvetch can be used as a complimentary species in dryland pasture plantings. It is considered succulent and its foliage is highly palatable to livestock and big game. Utah sweetvetch is a legume capable of fixing nitrogen. Planting should be done in early spring or late fall. Inoculation with the proper rhizobium will enhance nitrogen fixation. Germination occurs within 6 to 30 days. Utah sweetvetch is moderately tolerant of grazing. Utah sweetvetch has been reported to spread rhizomatously but only has moderate competitiveness. 'Timp' is the only cultivar available. https://plants.sc.egov.usda.gov/DocumentLibrary/plantguide/pdf/pg_hebo.pdf

Trefoil, Birdsfoot (*Lotus corniculatus*) is a moderate to long-lived herbaceous perennial legume. It has a well-developed, branching, tap-like root with side roots near the soil surface; there are some releases now with rhizomatous root systems. Most cultivars are erect and grow to a height of 2 to 3 feet (60 – 90 cm). The stems are slender, branch well, and are moderately leafy. Leaves are smooth and consist of 5 leaflets. The bloom is made up of a cluster of bright yellow flowers arranged in a whorl at the end of the flowering stems. The plant remains green and succulent during and after seed ripening. It is planted in combination with grass and grazed as a non-bloating legume. Birdsfoot trefoil can yield well on deep, well-drained soils receiving irrigation or adequate rainfall. As a dryland pasture legume, birdsfoot trefoil produces more growth after July 1 than most dryland grass legume mixtures.

Birdsfoot trefoil is generally planted in areas that receive 20 inches (508 mm) of precipitation or more. It is suited

to low and moderately fertile soils with relatively poor internal drainage, but is usually less productive than alfalfa on fertile, deep, well-drained soils. It performs well on soils too shallow or too poorly drained for alfalfa. It is equal to alfalfa in tolerance to saline-alkaline soils and is adapted to soils of medium acidity. The best pH range for establishment is 6.0 to 6.5 though it tolerates a broader pH range of 5.5 to 7.5.

Birdsfoot trefoil seedlings are slow to establish. Close grazing that takes all stem growth is very detrimental to regrowth and stand life. Delay spring grazing until plants are at least 8 inches (20 cm) high. Allow 24 to 38 days regrowth between grazings and leave a 4 inch (10 cm) stubble after grazing. Additionally, 60-day rest periods, every 3 years, helps to maintain the stand. Birdsfoot trefoil must be allowed to grow to maturity every third year or so, in order to produce a seed crop to maintain the stand. Hay harvest should leave 4 to 6 inches (10 – 115 cm) of stubble to ensure good regrowth. It is important to not graze from September to October until after a hard frost in the fall so Birdsfoot Trefoil can replenish carbohydrates in the root system.

Birdsfoot trefoil does not cause bloat in ruminant animals and does have anti-parasite intestinal attributes. European types are the most common upright or hay-type varieties used in west like 'Cascade' (France), 'Granger', 'Mackinaw' (IA naturalized), and 'Kalo' (France). Other varieties include 'Norcen', 'Viking', 'Mansfield', and 'Fergus', and 'Leo'. Empire types are varieties 'Empire' and 'Dawn' which are better adapted for grazing, are low-growing, pasture-type varieties. The European trefoil is not a variety, but merely refers to trefoil seed imported from Europe. https://plants.sc.egov.usda.gov/DocumentLibrary/factsheet/pdf/fs_loco6.pdf

Sainfoin (*Onobrychis viciifolia*) is an introduced, moderately lived, non-bloating, perennial legume. It grows from a root crown on a deeply penetrating taproot early in the spring and flowers one to two weeks earlier than alfalfa, which makes it an early season flowering species for pollinator habitat plantings. The stem is hollow, reddish-brown with straight hairs, and grows to a height of about 3 feet (90 cm) or more. The leaves are pinnately compound with 11 to 29 leaflets. The leaflets are longer than wide and taper abruptly to small sharp points. Condensed tannins in the leaves reduce the risk of bloat in ruminant livestock and reduce nematode parasitism in sheep. The small, fragrant flowers are pink to lavender with reddish-purple lines.

Sainfoin is adapted to up to elevations of 6,000 feet (1,829 m). It grows and yields best on deep, well-drained soils with a pH of 7.0 to 8.0, with mean annual precipitation of 13 or more inches (330 mm). It is frost and drought tolerant, resistant to bacterial wilt, and a good forage legume for sites with calcareous soils, late spring

frosts, and plentiful spring and early summer precipitation. In areas where dryland hay production is limited to one cutting, or when there is a shortage of irrigation water, it may prove a good substitute for alfalfa (*Medicago sativa*). Sainfoin has a feed value similar to alfalfa, but is preferred over alfalfa by cattle, sheep, deer, and elk. It is well suited to mechanical harvesting as it grows upright and is easily harvested. Since growth occurs up to full bloom, the first cutting can be taken at about the half- to full-bloom stage. Unlike alfalfa, sainfoin does not drop its lower leaves, and stems remain succulent as the plant matures. As a result, forage quality does not decrease as rapidly after the 10% bloom stage. Avoid cutting or grazing sainfoin too closely as it does not store carbohydrates during the summer and relies on photosynthesis by existing leaves to provide the necessary energy for re-growth. Allow six weeks of grazing rest before the first killing frost in the fall to facilitate the carbohydrate root storage needed for winter survival. Cutting a hay crop or grazing sainfoin after dormancy is recommended. Sainfoin has excellent forage quality and palatability making it an excellent choice for pasture. Although its productive lifespan may be less than other species, grazing sainfoin in the bud or early bloom stage and keeping the grazing height above 8 inches (20 cm), can lengthen the productive life from two or three years to six years. Sainfoin yields more when planted with either birdsfoot trefoil (*Lotus corniculatus*) or black medic (*Medicago lupulina*). Sainfoin is adapted to dryland pastures and grows satisfactorily in mixtures with bunchgrasses.

For root nodule formation and nitrogen fixation, the seed must be inoculated with sainfoin-specific *Rhizobium* bacteria just prior to planting. Sainfoin has poor tolerance to close or frequent grazing and animal trampling. Its slow growth makes it best suited for rotational grazing systems. The productive life of sainfoin is related to such factors as clipping height, competition from other forages and weeds, and frequency of irrigation. Irrigating sainfoin in the same manner as alfalfa will cause rapid stand decline. Sainfoin typically requires about 50% of the irrigation water needed by alfalfa. Sainfoin requires / must have good drainage, and has a low tolerance to excessive soil moisture, flooding, water logging, or even a high-water table and performs poorly on acidic or saline soils. It is shade intolerant. Older Sainfoin varieties are shorter-lived where root and crown rots are a problem and can still be a problem with newer varieties. Releases (year and location) of sainfoin varieties include 'Delaney' (2007, Wyoming), 'Shoshone' (2005, Wyoming), 'Nova' (1980, Canada), 'Renumex' (1977, New Mexico), 'Remont' (1971, Montana), 'Melrose' (1969, Canada) and 'Eski' (1964, Montana).

https://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/mtpmctn12043.pdf

Table 1. Inoculant code for different legume species.

Rhizobium Inoculants for Legume Species		
Common Name	Scientific Name	Inoculant Code
Alfalfa	<i>Medicago sativa</i>	A
Alfalfa, falcata	<i>Medicago sativa</i> subsp. <i>falcata</i> (L.) Arcang	A
Clover, alsike	<i>Trifolium hybridum</i> L.	B
Clover, berseem	<i>Trifolium alexandrinum</i>	R
Clover, crimson	<i>Trifolium incarnatum</i>	R
Clover, kura	<i>Trifolium ambiguum</i> Bieb.	Trifolium Sp. 3
Clover, prairie, purple	<i>Dalea purpurea</i>	F
Clover, prairie, western	<i>Dalea ornata</i> (Douglas) Eaton & Wright	
Clover, red	<i>Trifolium pratense</i>	B
Clover, strawberry	<i>Trifolium fragiferum</i> L.	
Clover, sweet (yellow or white)	<i>Melilotus officinalis</i>	A
Clover, white	<i>Trifolium repens</i>	B
Lupines, Russell	<i>Lupinus</i> spp.	H
Medic, black, bur, button	<i>Medicago</i> spp.	N
Pea, Austrian winter	<i>Pisum sativum</i>	EL
Pea, singletary, caley	<i>Lathyrus hirsutus</i>	C
Sainfoin	<i>Onobrychis viciifolia</i>	F
Soybean	<i>Glycine max</i>	S
Soybean, wildlife	<i>Glycine soja</i>	S
Sunn Hemp	<i>Crotalaria juncea</i>	EL
Sweetvetch, Utah	<i>Hedysarum boreale</i> Nutt	
Trefoil, birdsfoot	<i>Lotus corniculatus</i>	K
Vetch, big flower	<i>Vicia grandiflora</i>	C
Vetch, Canadian milk	<i>Astragalus canadensis</i> L.	
Vetch, cicer milk	<i>Astragalus cicer</i> L.	Astragalus Sp. L.
Vetch, deer pea	<i>Vicia ludoviciana</i>	C
Vetch, crown	<i>Securigera varia</i>	C
Vetch, hairy	<i>Vicia villosa</i>	C

Source: Natural Resource Conservation Service Technical Note No:TX-PM-15-01, February 17, 2015.

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Non-Legume Forbs for the Dryland and Irrigated PNW

Burnet, Small (*Sanguisorba minor*) is an introduced, hardy, herbaceous, relatively long-lived, evergreen, perennial forb. Plants are 10 to 22 inches (25 - 55 cm) tall and has a prominent taproot and can be weakly rhizomatous. Small burnet grows on rangelands in western North America. It grows best on calcareous soils but, is not restricted by soil type or texture. Small burnet grows on relatively infertile, well-drained soils and is most productive on silty or loamy soils with annual precipitation of 14 inches (350 mm) or greater. It will establish, but not persist on drier sites (down to 12 inches (300 mm) annual precipitation) or shaded or poorly drained soils. It is adapted to a broad range of elevation from 100 feet (30.5 m) to 8,900 feet (2,712 m) in elevation. Small burnet has good-to-excellent forage value for livestock and wildlife during all seasons. It stays green throughout the growing season and into winter until heavy snow cover occurs, providing forage and seed to livestock and wildlife.

Seedling vigor is excellent, but the plant establishes slowly. Germination normally occurs the first growing season if adequate moisture is available. Full flowering should not be expected, until at least the second growing season. Growth of small burnet begins in early spring and flowers appear in late May through June. The plant establishes slowly and should not be grazed until at least the second growing season. Small burnet plants have been known to persist for more than 20 years on western rangelands. As with other species, the life of the plant can be prolonged, if it is permitted to set seed occasionally. 'Delar' is the only variety available.

https://plants.sc.egov.usda.gov/DocumentLibrary/plant-guide/pdf/pg_sami3.pdf

Chicory, Forage (*Cichorium intybus*) is an introduced, large leaved, forb with a large deep taproot. It is a biennial to short-lived (3-5 years) perennial plant. It is a cold and heat tolerant, very palatable, and high quality forage plant. It is a plant high in minerals. It does have good anti-parasitical properties (leaves contain sesquiterpene lactones) that makes it valuable as part of pasture mix. It is not 100% effective and therefore should only be used as part of the parasite management program. Grazing the plant between 3 inches (7.5 cm) and 8 to 10 inches (20 - 25 cm) is best management. The plant can and will bolt, which will allow it to reseed itself and/or will require some clipping to keep it in vegetative growth

stage. Planting recommendations would be for higher precipitation areas and irrigated pastures. It does have some drought tolerance but will likely not survive in dryland pastures in the Inland PNW. There are numerous varieties and there are reported differences in palatability and sesquiterpene lactones concentration.

<https://www.nrcs.usda.gov/sites/default/files/2022-09/Chicory.pdf>

Kochia, Forage (*Bassia prostrata*) subspecies *virescens* and *grisea*) is an introduced, semi-evergreen, "half-shrub". Plants are 1 to 2.5 feet (30 to 75 cm) tall with a deep taproot and an extensive fibrous root system, and it may live up to 10 to 15 years. Although it is commonly only medium-lived; it readily re-establishes from seed. Forage kochia should not be confused with its weedy relative. Seed stalks and upper stems turn red in late summer and fall, while the lower branches retain a green appearance year-round. Flowers bloom from July to September. It grows within a range of at elevations ranging from 1,600 to 7,300 feet (490 to 2,200 m).

Forage kochia is well suited to dryland pastures and rangelands receiving 6 to 16 inches (15 to 40 cm) of annual precipitation and is adapted to a wide range of soil textures including sands, gravels, clays, silts and loams, but do best in medium-textured soils. Forage kochia is highly saline and sodic tolerant. Plants perform well and will spread on high saline sites including slick spots. Forage kochia is highly nutritious to cattle and can be used for standing fall and winter forage as an alternative to harvested hay. Forage kochia plants do not develop nitrate accumulation or oxalate toxicity.

Forage kochia begins growth at very cool temperatures and thus photosynthesizes at the same time of year as cheatgrass, providing direct competition for limited water resources. Forage kochia is well adapted to the very dry areas of the region and establishes easily. Plants are competitive against annual weeds. The best establishment comes from dormant fall or winter plantings which allow the seed to germinate and begin growth very early in the spring. Seed should be broadcast, aerially seeded, or drilled onto the soil surface, which has been lightly disturbed by harrowing or spread directly onto snow. Seed drilled and pressed into soil to depths more than 1/16 inches (1.5 mm) will rarely germinate or establish. Forage kochia seed loses viability quickly, even when processed and stored under proper conditions. Always use current year's seed that has received a recent germination test to ensure the best chances for establishment success. Forage kochia can be used as year-round forage under proper management. Spring grazing can be more detrimental to forage production than fall or winter grazing; however, livestock rarely graze it during the spring when green

grass is available. Plants grazed to less than two inches will show reduced growth the following year.

Cultivars available are 'Immigrant' (subspecies *virescens*) which grows to 12 to 15 inches (30 - 37.5 cm) in height, which does not work as well for winter grazing. 'Snow-storm' (subspecies *grisea*) grows upwards to 30 inches (75 cm) in height, which works well for winter grazing, and has improved stature, productivity and nutritional content compared to Immigrant. It produces 68% more forage, has 22% higher protein content, and is 4% more digestible than Immigrant.

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Plantain, Forage (*Plantago lanceolata*) is an introduced, perennial, deep-tap-rooted, drought tolerant forb. It is high in mineral content, palatable, with high quality. It works well as part of a pasture mix. It does not have any anti-parasitical value like chicory. Minimum annual precipitation requirements are moderate to high rainfall and irrigated conditions. There are a number of varieties to select.

<https://keys.lucidcentral.org/keys/v3/pastures/Html/Plantain.htm>

New Forage Kochia Doubles Yields

<https://www.drovers.com/news/new-forage-kochia-doubles-yields#:~:text=Research%20in%20eight%20western%20U.S.,crop%20also%20has%20higher%20digestibility>

Plantain (Dairy NZ)

<https://www.dairynz.co.nz/feed/crops/plantain/>

Plantain establishment:

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Appendix Chapter 5

Growth, Development, and Defoliation Responses of Pasture Plants

¹Steve Fransen and Tom Griggs

The University of Idaho Extension gives permission to reprint chapter 5 from PNW 614 in a new Inland Pasture Calendar bulletin. Reprinted by permission of the publisher from S. Fransen and T. Griggs, “Growth, Development, and Defoliation Responses of Pasture Plants,” pp.41-52 in *Pasture and Grazing Management in the Northwest (PNW 614)*, Glenn E. Shewmaker and Mylen G. Bohle (eds.). Moscow, ID: University of Idaho Extension. Where appropriate Appendix Chapter citations are added. Also added are authors current contact information.

PASTURES TYPICALLY PROVIDE THE LOWEST-COST SOURCE OF

FORAGE (energy) in any livestock operation. Well-maintained irrigated pastures have few weeds, grow rapidly, produce high-quality herbage for high animal intake, and recover rapidly following grazing. Without periodic rest and recovery, however, the productivity of irrigated pastures is often less than their potential. The keys to having more productive land and more profit are to adopt Management-intensive Grazing (MiG) and to understand how plants grow. Then, by monitoring and managing the structure, growth stage, physiology, nutritional value, and defoliation of pasture plants, you can improve your ability to do the following:

- Predict plant responses to environmental conditions and management
- Recognize when plant growth is reduced by deficiency of a particular nutrient
- Optimize the productivity, seasonal growth distribution, nutritional value, persistence, and species composition of your pastures

In this chapter, we provide the knowledge needed to optimize pasture growth and productivity. We discuss plant structure, forage growth patterns, and the importance of energy reserves and residual leaf area for plant regrowth. Grazing guidelines based on these factors are provided for grasses, legumes, brassicas, other forbs, and mixed pastures. Other important considerations for

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Key Points

- Understanding the positions and activities of plant growing points allows you to predict pasture growth rates, species proportions in regrowth of mixtures, and quantities of regrowth.
- Pasture growth rates vary widely across the growing season, with peak productivity in late spring to early summer.
- Forage species differ in plant structure and their response to defoliation.
- Regrowth of grazed plants requires energy from sunlight (captured by live leaves) and mobilization of stored reserves. Thus, both green leaf area and stubble are important. The relative importance of these two energy sources varies among species, with implications for target stubble heights.
- In grasses, energy reserves are stored primarily above ground in stem bases. In taprooted legumes, energy reserves are stored primarily below ground. Thus, grasses typically require higher stubble heights after grazing.

grazing management include animal nutrition and forage quality.

The morphological basis of defoliation management

Understanding plant structure (also called morphology) and how structure varies among species is important to grazing management. In this section, we discuss key plant structure characteristics as they relate to grazing management.

PLANT SHOOT STRUCTURE

Grasses and legumes are composed of repeating modules or subunits (phytomers). Each phytomer contains a leaf and bud attached to a node (joint) that is positioned at the base of an internode (figure 5.1). A fully developed leaf consists of a blade and sheath in grasses, or leaflets and a petiole in legumes. A shoot is a collection of phytomers, sometimes including an inflorescence. In grasses, a shoot is usually called a tiller. We will use the term shoot, however, as this term applies to both grasses and legumes.

In some cases, internodes are elongated and connected by visible, palpable nodes. Elongated internodes and intervening nodes are often referred to as “true” stem. In other cases, internodes are compressed (unelongated), and nodes can be neither seen nor felt (1A in figure 5.2). A plant with a collection of unelongated internodes and intervening nodes may be referred to as “stemless.” Thus, shoots may range from having visible leaves but no visible stem to having leaves attached to an elongated stem with or without an inflorescence (figure 5.2). As shoots age, leaves die and may fall off of the lowest nodes.

The life span of a shoot is typically less than one growing season or year. Depending on the growth stage at grazing or cutting, many annual forages have little or no regrowth potential during a growing season. Most perennial pasture species, on the other hand, can have multiple growth cycles during a season. The persistence of perennial grasses and legumes over multiple seasons is based on a succession of short-lived or annual shoots. Perennials are able to live for multiple years because some of their growing points can survive the winter and resume growth during the next growing season.

MERISTEM LOCATIONS AND ACTIVITIES

Growing points, also known as meristems, are sites of cell division and growth. Meristems give rise to new leaves, stems, roots, and inflorescences, as well as to additional meristems and new shoots. There are three meristematic

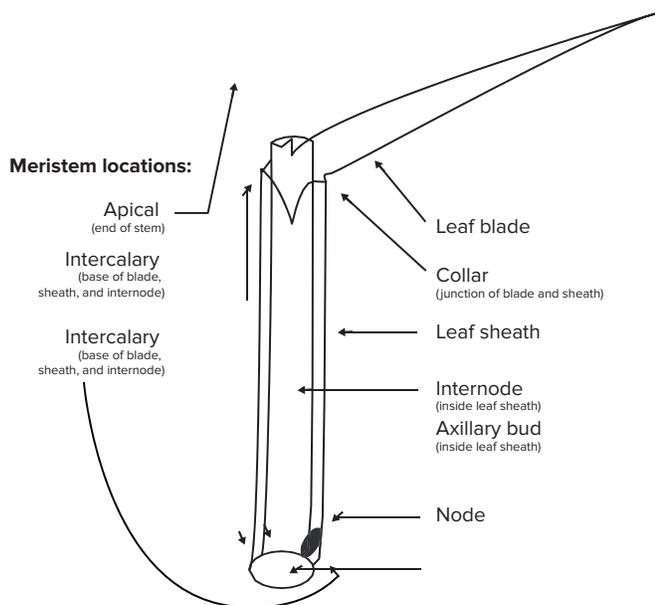


Figure 5.1. Locations of meristems and components of a grass phytomer, the repeating subunit of plant structure. A fully developed grass leaf consists of a blade and sheath joined at the collar, which forms when the leaf is fully elongated. On a legume phytomer, the leaf consists of multiple leaflets at the end of a petiole that is attached to a node.

Key Terms

Crown—Junction where plant shoots and roots meet, near the soil surface. A pasture plant may have a single shoot or multiple shoots arising from the same crown.

Inflorescence—Reproductive portion of a plant (flowers or seedhead). Found at the terminal ends (tops) of tillers or branches.

Long-shooted species—A species whose internodes elongate during vegetative growth.

Meristem—A growing point, or site of cell division and growth. Apical meristems give rise to new leaves, stems, roots, and inflorescences, as well as to additional meristems and new shoots. Intercalary meristems give rise to leaf growth and regrowth from the collar.

Phytomer—A single module of a plant shoot. Each phytomer contains a leaf and bud attached to a node that is positioned at the base of an internode.

Shoot or tiller—A collection of phytomers, often called a tiller in grasses and a shoot or branch in legumes.

Short-shooted species—A species whose internodes do not elongate during vegetative growth.

Vernalization—Process of inducing plant flowering through environmental signals (decreasing day length and/or low temperatures) during fall or winter. Vernalized shoots flower and set seed during the following growing season.

sources of tissue growth in grasses and legumes: apical, intercalary, and axillary meristems (figure 5.1). Each of these meristems is described below.

Meristems are important because they are the source of all plant growth. In later sections of this chapter, we will see how the positions and activities of meristems vary (depending on species, plant growth stage, and plant height) and how those differences affect grazing decisions.

Apical meristems

An apical meristem (also known as a shoot apex or root apex) is located at the growing end of each stem and root. Note that stolons and rhizomes are stems that grow horizontally above or below the soil surface. They have the same structure as a vertical stem, including an apical meristem at the growing end.

A vertical stem is short and remains near ground level if internodes have not elongated (1A, 2A in figure 5.2).

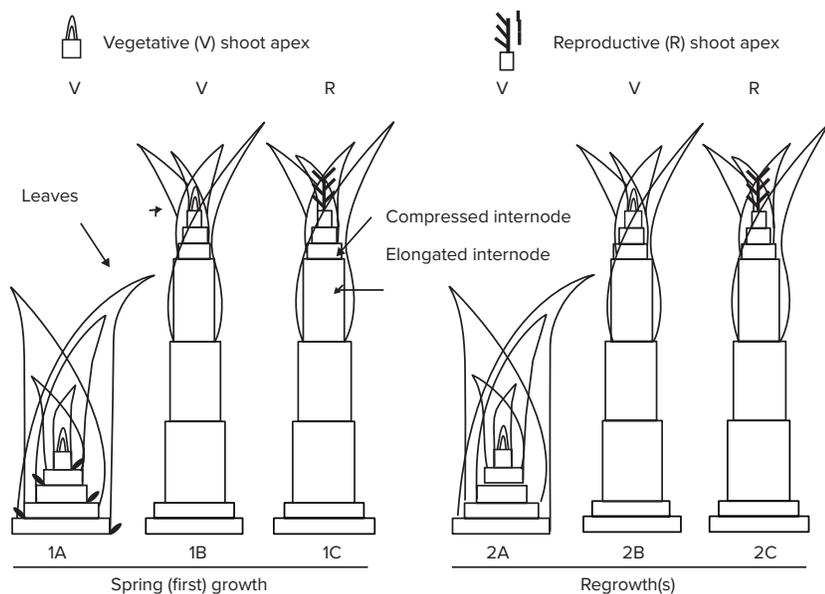


Figure 5.2. Differing growth patterns of grass tillers during spring and regrowth cycles following defoliation (V = vegetative, R = reproductive shoot apex). All shoots have axillary buds as in 1A. Shoots 1A and 2A are vegetative shoots of short-shooted species with a vernalization requirement for flowering. Shoots 1B and 2B are vegetative shoots of long-shooted species with a vernalization requirement for flowering. Shoot 1C is a reproductive shoot of a short- or long-shooted species that (a) formed the previous fall and has a vernalization requirement for flowering, or (b) formed in spring and has no vernalization requirement for flowering. Shoot 2C is a reproductive shoot of a short- or long-shooted species that formed in summer and has no vernalization requirement for flowering. Shoots 1A and 1B were vernalized the previous fall, survived winter, and shifted to 1C in spring. Shoots 2A and 2B formed during summer and remained vegetative during a regrowth cycle because they were not vernalized. If shoots 2A or 2B did not have a vernalization requirement for flowering, they could shift to 2C.

A stem can be in a vegetative (1A, 1B, 2A, 2B) or reproductive (1C, 2C) stage, depending on the tissues produced by the apical meristem. A vegetative apical meristem produces leaves, internodes, nodes, root initials, and axillary buds below it, but does not produce inflorescences. It remains positioned above the most recently generated tissues.

Root initials are specialized meristematic cells located at the bases of internodes. They may generate so-called nodal or adventitious roots at a later date. These nodal roots form at the base of a shoot and near nodes on rhizomes and stolons. These are the meristems that allow cuttings to root after planting.

A vegetative apical meristem can continue generating leaves and other phytomer parts until it is removed by defoliation (if elevated, 1B, 2B), dies due to age or shading in a dense canopy, or shifts to reproductive status (1C, 2C). Once an apical meristem shifts to reproductive status, it produces an inflorescence and shoot growth ceases. Any replacement growth, regardless of whether the reproductive shoot is defoliated, must arise from axillary buds, as explained below.

Apical meristems also produce the other two types of meristems described below, so in a sense, apical meristems are the source of all forage plant growth; above ground, below ground, and horizontal.

Intercalary meristems

An intercalary meristem is located at the base of each leaf blade, leaf sheath, and internode (figure 5.1). These meristems allow tissues to elongate. At certain times of the year, the intercalary meristems on internodes are inactive on many species; thus, internodes remain compressed. The lowest one or more internodes (those nearest the crown) often remain unelongated throughout the life of a shoot, even if internodes above the crown eventually elongate (1B, 1C, 2B, 2C in figure 5.2).

An active intercalary meristem that remains following defoliation can continue to generate new tissue until the leaf or internode is fully expanded. Grass leaves, which

differentiate blades and sheaths as they mature, can continue expanding until formation of the collar at the junction of blade and sheath (figure 5.1). This growth from intercalary meristems is easily observed

in mowed lawns, where young, uncollared grass leaves continue to lengthen after their tips have been clipped off.

Axillary meristems

The axil is the angular junction at which a leaf is attached to a node. An axillary meristem (also known as a tiller bud, crown bud, or basal bud) is located in each axil (shown only in 1A in figure 5.2; assume that all shoots have them). When a shoot arises from this growing point, the axillary meristem becomes the apical meristem of the new shoot.

Axillary buds often are inactive until their parent shoot reaches maturity or until the apical meristem is removed. In many grasses and legumes, axillary buds at higher nodes remain inactive throughout the life of the shoot. Reed canarygrass is a cool-season grass that can activate upper axillary buds, often at heights of 3 or 4 feet, during summer growth. Reed canarygrass must be in a moist environment (usually without being grazed or cut for hay) in order for these new aerial shoots to form from axillary buds. These unusual new shoots are easy to miss when walking in the field, but on close inspection they

look so out of place that you'll likely think you're seeing double, and you are!

If an apical meristem is removed, leaf and internode growth may continue from intercalary meristems for a limited time. However, shoot replacement (i.e., the next crop of short-lived shoots) can occur only from axillary buds.

New shoots can also emerge from axillary buds on stolons (white clover) and rhizomes (quackgrass, smooth brome, Kentucky bluegrass, and reed canary-grass), as can new roots from near nodes. This process of new shoot formation is referred to as tillering. See Briske (1991) and Manske (1998) for more information on grass developmental morphology.

Understanding forage growth patterns

Volumes have been written about plant growth and development, but if you simply understand the basics of this topic, grazing management becomes easier. The important concepts to understand relate to new shoot formation, induction of flowering, internode elongation, leaf maturity and senescence, sources of energy for regrowth, and seasonal distribution of pasture growth. Each of these topics is discussed below.

NEW SHOOT FORMATION

Tillering, or the formation of new shoots, replaces older and dead shoots. It increases the live shoot density of plants, thereby filling gaps in the pasture canopy. In most perennial cool-season grasses, only the axillary buds at the crown region of the parent tiller form new tillers. In many legumes, tillering can occur from axillary buds at various positions at or above the crown.

Grass species vary in the timing of shoot formation:

- In many perennial grass species, new shoots form from axillary buds in spring and fall.
- In some species, such as Kentucky bluegrass, orchardgrass, perennial ryegrass, and tall fescue, new shoots form at a relatively constant rate throughout the growing season. This continuous shoot formation occurs regardless of the developmental stage or defoliation history of the parent shoots. This trait is desirable in turf and pasture grasses for continuity of growth.
- In other species, new shoots form in pulses or waves as the parent shoots reach maturity or are defoliated. This pattern of shoot development is common in taller-statured hay grasses (e.g., timothy, smooth brome, intermediate wheatgrass, and some warm-season perennial grasses such as switchgrass) and in legumes such as alfalfa.

VERNALIZATION

In many species (including most cool-season perennial grasses), environmental signals that occur during fall or winter induce plants to flower and set seed during the following growing season. This process is known as vernalization. It occurs in response to decreasing day length and/or temperature during fall or winter.

Fall-planted seeds can be vernalized in some cases, but shoots are the main receptors of the winter signal.

Only shoots that are present in fall or winter can be vernalized. Those that survive until spring can then flower in response to increasing day length and/or temperature (1A and 1B become 1C in figure 5.2).

In species with a vernalization requirement, shoots that originate in spring or summer will remain vegetative and will not develop reproductively during that growing season (2A, 2B). Thus, spring-seeded plants

that have a vernalization requirement will not develop seedheads during their first growing season.

Most pasture legumes do not have a vernalization requirement. They develop to reproductive stages during each spring and summer growth cycle if not defoliated.

INTERNODE ELONGATION AND REPRODUCTIVE DEVELOPMENT

In some grasses (known as short-shooted species), internode elongation coincides with a shift from vegetative to reproductive development. In other species (long-shooted species), internodes can elongate while vegetative growth continues. Legume internodes usually elongate throughout each growth cycle, regardless of their reproductive status.

Once internodes elongate, the apical meristem becomes vulnerable to removal through grazing or mechanical harvesting. *Thus, pasture plants respond differently to defoliation depending on whether internodes elongate during vegetative growth.*

Short-shooted (SS) species

Species with short shoots are not necessarily short-statured plants, but their internodes do not elongate during vegetative growth (1A, 2A in figure 5.2). Thus, their apical meristems remain protected on stemless shoots near ground level. These species are considered more defoliation-tolerant than long-shooted species.

At some point in the growing season (typically in the first growth cycle for grasses), the apical meristem of a short-shooted species may shift from vegetative to reproductive status (1A to 1C in figure 5.2). At this time, internode elongation may elevate the apical meristem, making it susceptible to removal by grazing early in the growth cycle.

Examples of short-shooted species are Kentucky bluegrass, orchardgrass, perennial ryegrass, tall fescue, and meadow brome (table 5.1).

Table 5.1. Common long-shooted (LS) and short-shooted (SS) irrigated forage grasses and their growth characteristics.

Species	LS/SS	requirement	development
<i>Big bluestem</i>	LS	No	<i>Pulses</i>
<i>Italian (biennial) r yegrass</i>	SS	Yes	<i>Season-long</i>
<i>Indiangrass</i>	LS	No	<i>Pulses</i>
<i>Kentucky bluegrass</i>	SS	Yes	<i>Season-long</i>
<i>Meadow brome</i>	SS	Yes	<i>Season-long</i>
<i>Meadow fescue</i>	SS	Yes	<i>Season-long</i>
<i>Orchardgrass</i>	SS	Yes	<i>Season-long</i>
<i>Perennial r yegrass</i>	SS	Yes	<i>Season-long</i>
<i>Smooth brome</i>	LS	Yes	<i>Pulses</i>
<i>Switchgrass</i>	LS	No	<i>Pulses</i>
<i>Tall fescue</i>	SS	Yes	<i>Season-long</i>
<i>Timothy</i>	LS	No	<i>Pulses</i>
<i>Westerwolds (annual) r yegrass</i>	SS	No	<i>Season-long</i>

Long-shooted (LS) species

In species with long shoots, internodes are elongated during both vegetative (1B, 2B in figure 5.2) and reproductive (1C, 2C) growth. In other words, internodes are always elongating. In the case of rhizomes and stolons, elongation is lateral.

This elongation exposes apical meristems on shoots to defoliation even if the grass is not overgrazed. These species are considered more defoliation-sensitive and must be better managed to maintain stands in pastures.

The recovery rate for regrowth is slower for long-shooted grasses than for short-shooted species. Some long-shooted species, e.g., timothy, smooth brome, and alfalfa, may also have low energy reserves and a limited basal leaf area during internode elongation prior to flowering. These characteristics make these species even more sensitive to defoliation.

Other long-shooted grass species include reed canarygrass and intermediate wheatgrass. Legumes are long-shooted species.

Timing of internode elongation

On established perennial grasses (both short-shooted and long-shooted), reproductive shoots with elongated internodes tend to develop during the primary (first) growth cycle of the season (1C in figure 5.2). Growth patterns diverge as follows during subsequent re-growth cycles:

- Species with a vernalization requirement for flowering will not develop reproductively (2A, 2B). Those without a vernalization requirement may do so (2C).
- On short-shooted species, internodes will not elongate unless they become reproductive. Long-shooted

species and legumes will elongate internodes in both vegetative and reproductive phases.

As perennial forage plants grow taller and mature, upper-canopy leaves shade the lower leaves. These older, shaded leaves turn yellow and brown as they senesce (die). Some detach from lower nodes

These differences are important because they mean that short-shooted species with a vernalization requirement will remain vegetative on stemless shoots during regrowth cycles. This growth habit means a high leaf concentration and that the apical meristem will continue to be protected from grazing throughout the growing season. Many cool-season perennial grasses fall into this category. (Timothy is an exception.)

Most perennial warm-season grasses have no vernalization requirement and tend to be long-shooted, so they develop reproductive shoots with elongated internodes during regrowth cycles. These grasses, e.g., switchgrass, big and little bluestem, and eastern gamagrass are considered short-day plants and flower in response to changes in day length.

LEAF MATURITY AND SENESCENCE

Following grazing, the intercalary meristems on the grass leaf will regrow rapidly until the collar region forms as blade and sheath elongate fully. At that time, the intercalary meristems stop growing, and the leaf has reached its maximum dry weight (yield, figure 5.2), but those that remain have some capacity to store nutrients and sugars, which can be mobilized for active regrowth or winter survival. As the entire plant matures, these soluble materials are moved to the stubble and crown. Storage may be more pronounced in some grasses (e.g., timothy, smooth brome, reed canarygrass, and switchgrass) than others, but it's important for all forage grasses.

Grasses vary in how many actively growing leaves they can sustain at any time. For example, many perennial ryegrass shoots sustain only 3 leaves, while a timothy shoot may sustain more than 10 leaves at a time.

SEASONAL DISTRIBUTION OF PASTURE GROWTH

Under most conditions in the Northwest, daily pasture growth rates for cool-season grasses fluctuate widely during the growing season. As shown in figure 5.3, the pasture growth rate usually peaks as a function of temperature in late spring and declines during hotter summer temperatures.

These growth patterns were demonstrated by a 3-year study at Klamath Falls, Oregon. Dovel and Rainey (1999) compared pasture yields of 24 cool-season perennial grasses over 3 years. Yields were lower in 1997 due to a colder spring that delayed grass growth compared to other study years. Daily growth rates in 1996 and 1998 were similar, due to more typical seasonal temperature

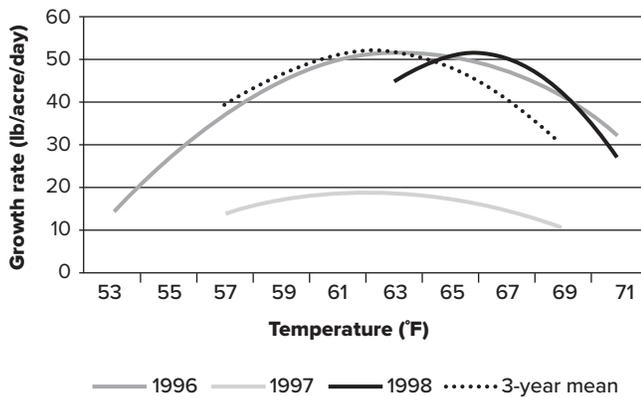


Figure 5.3. Daily growth rate of irrigated perennial cool-season grass managed as simulated grazing (Klamath Experiment Station, Oregon State University). (Source: Dovel, R.L. and J. Rainey. 1999. Pasture and hay grass variety trial, 1998. In: Research in the Klamath Basin, 1998 Annual Report. Special Report 1007. Agricultural Experiment Station, Oregon State University)

conditions, although the spring of 1998 was wetter than normal.

Spring

During early-spring growth (i.e., when temperatures are below 60°F), grass growth is slow. Growth rates then increase during the spring flush period, as soil water is usually adequate, temperatures are optimum, a second generation of roots is growing, and grass stems are elongating.

Fertilization practices can maximize forage growth during this period. In early spring, new root growth begins underground 1 to 4 weeks before new shoots appear. These new roots have immediate access to nitrogen (N) that becomes available as soils warm and microorganisms break down organic matter. Research at Oregon State University evaluated the T-sum system of applying the first N in the spring. The T-sum system is based on accumulation of growing degree days (GDD) starting on January 1. Cool-season grass yield during the spring flush is significantly higher if N is applied when 200 GDD have accumulated, rather than by the traditional calendar date. This response is partially explained by the ability of healthy new grass roots to utilize N applied during early spring (see chapter 3 for more information).

Summer

As the growing season advances, pasture growth rates decline in response to soil water deficiency (even in some irrigated systems), high temperatures, and often lower levels of soil N. At this time, cool-season grasses are shedding roots and most species are no longer elongating stems.

By late August, early mornings become cooler, afternoons are not as hot, and day length is decreasing. These are important environmental signals to pasture plants. For the next month, these dramatic climate changes continue, and grasses begin to regrow more rapidly.

Fall and winter

In the fall, color changes in leaves are very apparent as grasses prepare for winter dormancy. Fall is considered the beginning of the perennial cool-season grass cycle because grasses produce the first generation of roots and most of their apical meristems during this time. These apical meristems develop on basal shoots that arise from axillary buds. This process often begins in September or October and continues until freeze-up. In order to initiate this process, cool-season grasses must retain enough basal leaf tissue to “see” that days are shortening. Grasses transition into root shedding during the winter dormancy period before initiating new roots the following spring.

Implications for pasture managers

By understanding these seasonal growth patterns, you can improve the uniformity of growth through the season. Some strategies include the following:

- Appropriate irrigation and fertilization—For example, you might limit phosphorus (P) and potassium
- (K) fertilization in spring and apply these nutrients in the early fall to stimulate apical meristem development (see chapter 3).
- Complementary use of warm-season grasses
- Greater reliance on cool-season and deeper rooted species that continue growing well at higher summer temperatures—Examples include tall fescue, alfalfa, forage plantain, and chicory.
- Proper defoliation management (see “Grazing guidelines,” later in this chapter)

When the stocking rate is relatively constant throughout a grazing season, simply rotating livestock more quickly through paddocks may not prevent reproductive development of forage plants or the accumulation of surplus spring forage. Stockpiling this spring forage for later grazing usually is not a good solution because the stockpiled forage can limit regrowth and may be of very low quality by the time it is used.

Mechanical harvesting of surplus forage is an extremely effective tool for balancing seasonal forage supply and demand.

Note also that although irrigated pasture growth rates follow a predictable pattern, they can vary substantially from year to year (figure 5.3). Growth rates are a moving

target that pasture managers must monitor closely. Overgrazing of irrigated pastures can easily occur if grazing is managed by the calendar or without careful observation of grasses for leaf, shoot, root, and stem development. Each year is different, and management must be adjusted to compensate for unexpected changes in weather, equipment failure, or unplanned travel by the manager.

Energy reserves and residual leaf area for regrowth

ENERGY STORAGE

Plants capture sunlight energy and carbon dioxide (CO₂) from the atmosphere and convert them to chemical energy through photosynthesis. Some of this energy is stored for later use during regrowth. Without this energy supply, pasture production cannot reach its potential. Overgrazing and mismanagement that reduce energy storage will ruin the very best pasture.

Plants store energy as various forms of carbohydrates. Structural carbohydrates (cellulose and hemicellulose) and lignin form the fibrous materials in plant cell walls. Sugars are stored temporarily in leaf tissues and then are moved overnight to longer term storage.

In grasses, long-term storage is in the bottom 3 to 6 inches of the stubble and in stolons and rhizomes. Timothy also stores energy in corms (bulb-like structures found at the base of each tiller). Only small amounts of sugar reserves are stored in the fibrous roots of grasses.

These stored carbohydrates take the form of starch (in warm-season grasses) or fructosans (in cool-season grasses). Fructosans are chains of fructose with a terminal glucose. Glucose is only about 60 percent as sweet as fructose. Thus, where fructosans are the major storage sugar in the lower portion of the plant, livestock tend to overgraze in order to eat the sweeter portions of the plant (the basal stubble).

Unlike grasses, taprooted forbs such as alfalfa, red and other clovers, sainfoin, birdsfoot trefoil, and chicory store large amounts of reserve carbohydrates in their crowns and roots. Spreading legumes such as white and kura clovers and cicer milkvetch also store energy reserves in stolons and rhizomes.

Stored sugars are in a constant state of motion. After formation and movement to storage areas, they are mobilized and used as needed by the plant for regrowth.

MAXIMIZING CARBOHYDRATE PRODUCTION AND STORAGE

Live leaf area, including the residual leaf area that remains after grazing, is required for energy capture.

Thus, not every grass blade or legume leaf needs to be eaten to provide value to the pasture.

To maximize energy production and storage, you must maximize the *active* leaf area in the pasture canopy,

because this is the area that produces sugar for storage. In well-managed irrigated pastures, sunlight interception is high because nearly all of the soil is covered by grass and legume leaves and basal stems. In overgrazed pastures, bare soil or weeds often intercept a large portion of the sunlight, but they don't contribute to forage yield or quality.

When other factors are not limiting, pasture growth rates are highest when the canopy leaf area intercepts approximately 95 percent of incoming sunlight energy. This means that sunlight should penetrate all the way to the soil surface on only about 5 percent of the land area. Although there is seemingly lost production potential with these gaps, they are important in the pasture canopy. If leaf area exceeds this optimum level, shading reduces productivity and tillering and increases leaf death and loss. If leaf area is much smaller, then overgrazing likely has occurred and potential pasture yield or future regrowth will be lost.

The vertical canopy structure of grass leaf blades gives them an advantage over legume leaves (which are more horizontal) in capturing sunlight. This attribute can also be a disadvantage, however, because taller leaves have a greater chance of being overgrazed if not managed correctly.

REQUIREMENTS FOR REGROWTH

Plant regrowth following defoliation—either through grazing or cutting—requires a lot of energy. There are two sources of energy for regrowth: (1) sunlight energy captured by residual leaf area, and (2) energy reserves in the stubble, crown, and roots. In general, regrowth relies mostly on energy reserves until new leaf area can capture enough sunlight to meet plant energy needs.

Species differ in their relative reliance on these energy sources, however, depending on their capacity for energy

Table 5.2. Comparison of the relative dependence on different sources of energy for regrowth in common pasture grasses.

Species	Energy reserves	Sunlight capture
<i>Bluebunch wheatgrass</i>	x	
<i>Crested wheatgrass</i>		x
<i>Kentucky bluegrass</i>		x
<i>Meadow brome</i>		x
<i>Meadow fescue</i>		x
<i>Orchardgrass</i>	x	x
<i>Perennial ryegrass</i>	x	x
<i>Reed canarygrass</i>	x	
<i>Smooth brome</i>	x	
<i>Tall fescue</i>	x	x
<i>Timothy</i>	x	

storage and their basal leaf density (table 5.2). Because sunlight capture depends on leaf density, grasses with low basal leaf density have less ability to capture sunlight following regrazing. Thus, they depend more on stored reserves. Examples include timothy, smooth brome, reed canarygrass, and bluebunch wheatgrass.

Grasses with high basal leaf density rely more on sunlight capture by residual leaves. Examples include Kentucky bluegrass, orchardgrass, perennial ryegrass, tall fescue, meadow brome, and crested wheatgrass.

Among legumes, white clover, birdsfoot trefoil, and cicer milkvetch store smaller quantities of energy during the growing season and depend more on sunlight capture by residual live leaves. Alfalfa, red clover, and sainfoin rely more on stored root reserves.

Grazing guidelines

By understanding your grass species' regrowth requirements (reserve energy versus live leaf area) and knowing whether they are short- or long-shooted, you can assess their appropriateness for rotational versus continuous stocking and for various types of defoliation management (more frequent and severe versus less frequent and lax). This information can help you make better decisions about the following:

- The type of grazing system appropriate for your pastures
- The timing of grazing
- Targets for residual stubble after grazing
- Canopy height based on species of the pasture
- Management of mixed pastures
- Predictions of forage regrowth Start with the following information:
 - Are your species short-shooted or long-shooted? (table 5.1)
 - Do they have a vernalization requirement? (table 5.1)
 - What is their seasonal pattern of shoot development? (table 5.1)
 - Do they depend more on energy reserves or live leaf area for regrowth? (table 5.2)
 - Is the apical meristem elevated at the time of grazing? (your observation)

In this section, we'll see how you can use this information in grazing management decisions.

TIMING OF GRAZING

For well-adapted pasture grasses, such as perennial ryegrass, orchardgrass, and tall fescue, the three- to four-leaf stage is an excellent time for grazing. At this time, the pasture growth rate has been high, nutritional value

A practical grazing example

Let's look at an example of grazing management that takes into account plant regrowth patterns. We'll assume we have a sprinkler-irrigated pasture in the Pacific Northwest (Lost Buck Ranch) and want to raise beef steers. We'll purchase steers in January and background them until the established cool-season perennial pastures are ready to graze (mid-March to mid-April). On Lost Buck's sandy soils, we will plant endophyte-free tall fescue and a grazing-type alfalfa. On the silty soils, we'll plant orchardgrass, perennial ryegrass, and annual ryegrass, plus red and white clovers. On the clayey soils, we'll consider tall fescue again, or reed canarygrass or smooth brome mixed with Kentucky bluegrass and alsike, white, and strawberry clovers.

Our pasture consists of several paddocks used in rotation. We use fencing to create the paddocks and control the steers.

The steers go from winter hay backgrounding to early-spring pasture on the sandy soils that dry out first. They will then move to the silty-soil orchardgrass-ryegrass pastures during spring flush, then onto the clayey-soil pastures during spring flush and into early summer. Then they will be rotated back to the tall fescue-alfalfa during July, as these species will have regrown well after resting. During the fall flush regrowth, the steers will return to the orchardgrass-ryegrass mix, where there should be plenty of high-quality, high-protein, digestible-fiber forage. Depending on the year, we may want to graze into early winter on the regrowth of the clayey pasture mixture, but we will make sure never to graze too low.

This is just one example of how cool-season grass and legume mixtures and rotations could be part of the Lost Buck Ranch management plan.

As we learn more about perennial warm-season grasses, these species could become an important part of the summer growth cycle. They could fill a niche when cool-season grasses become summer-dormant or have slower growth and reduced quality.

is starting to decline but is still excellent, and the plant is in positive energy balance for rapid regrowth.

Research in the Pacific Northwest is limited for many taller-statured grasses such as smooth brome, timothy, and reed canarygrass. Consider grazing these species after at least the five-leaf stage.

TARGETS FOR RESIDUAL STUBBLE

Rotating grazing animals before they remove excessive leaf tissue allows for a mixture of younger and older leaves to fix carbon dioxide (CO₂), promoting regrowth. For most pasture grasses, overgrazing into the stubble, i.e., the "bank account," greatly reduces stand life and

pasture productivity and lengthens the time needed for regrowth before regrazing. More often than not, pasture production and quality are reduced long before they should be because the stubble height rule was violated. The result is increasing weed competition and bare soil areas.

The required stubble height for a particular species is related to the species' relative reliance on energy reserves or sunlight capture by residual leaf area for regrowth (table 5.2). Grasses that depend on stored reserves need relatively higher stubble for regrowth. Grasses that depend on sunlight capture by residual leaves may be a little more forgiving of shorter stubble heights, but they still require adequate leaf tissue to capture sunlight and form plant sugars quickly for regrowth and production. A good rule of thumb is to maintain a 3- to 4-inch stubble height for cool-season grass in irrigated pastures. Warm-season grasses require twice the stubble height (6 to 8 inches) of cool-season grasses. Stubble is also important to protect the plant crown from hoof damage and from wind and water erosion.

Taprooted legumes store considerable amounts of energy in their taproots. When grown in monocultures and allowed to store sufficient reserves between defoliations, as is typical under hay management, they can be grazed to within 1 inch of the soil surface (although a number of problems could arise from consistently managing legume pastures in this manner). When growing these species in mixtures with grasses for grazing, you must take into account the impact of defoliation on both the grasses and the legumes (see "Considerations for mixed pastures," below).

Leaving a higher stubble or residual leaf area generally allows for more frequent defoliation. By providing for higher stubble heights in your pasture management plan, you will ensure stronger stands with fewer weeds, more rapid regrowth after grazing, more consistent forage quality, and more sustainable production.

CONSIDERATIONS FOR MIXED PASTURES

To maintain productivity and desirable species proportions in a mixed pasture, grazing management—stubble height, residual leaf area, and frequency of defoliation—usually is determined by the species that is most sensitive to defoliation. For example, depending on the time of the growing season, you could graze a mixed pasture of white clover and Kentucky bluegrass or perennial ryegrass every 2 to 3 weeks to a stubble height of 1 to 2 inches or even less. (Note that such close grazing is possible only with high fertility management to keep these short-shooted grasses actively growing. Otherwise, the clover will quickly out-compete the grass in the summer, and the grass may not recover adequately in the fall.) A mixture of alfalfa and smooth brome, on the other hand, can be grazed only every 3 to 4 weeks to a

stubble height of 3 to 4 inches. Frequency and severity of grazing for mixtures of red clover with orchardgrass or tall fescue would fall between these extremes.

In overgrazed pastures, desirable grasses typically are severely grazed, allowing legumes or weeds to take over the stand. Because grass leaves are more vertical than legume leaves, they are easier to graze. Additionally, livestock are attracted by the higher sugar content in grasses. Thus, when grazing a grass-legume mixture, it is important to maintain the balance of forage species.

PREDICTING REGROWTH

Your knowledge of grass growth patterns can help you predict how your pasture will respond to defoliation. First, you need to know whether your grass species are short-shooted or long-shooted and whether they have a vernalization requirement (table 5.1). Then, monitor meristem positions and activities. Is the meristem elevated? Is it vegetative or reproductive? As discussed above, when apical meristems are elevated, they may be removed during grazing, thus reducing the rate of regrowth. Once you know how each species responds to defoliation, and consider the time during the growing season, you can better forecast and budget forage growth.

For example, smooth brome is a long-shooted species with a vernalization requirement. Smooth brome shoots emerge later in spring than those of other species such as Kentucky bluegrass, requiring livestock to remain longer on winter hay rations or other feeds until the grass has adequate height and yield for grazing. Growth during the spring flush will be rapid and high-quality. Regrowth after grazing will be very slow if apical meristems were removed, because re-growth from axillary buds is relatively slow. Thus, understanding the limited regrowth potential of this species allows managers to avoid overgrazing.

In contrast, Kentucky bluegrass is a short-shooted species with a vernalization requirement. Shoots emerge relatively early in spring, and pastures are quickly carpeted in green leaves. The growth rate increases with warmer temperatures, with the highest yields occurring during the spring flush. As summer temperatures increase and irrigation continues, re-growth may slow due to temperature stress. Nonetheless, regrowth following defoliation may be faster than that of long-shooted species due to regrowth from apical and intercalary meristems.

Additional considerations for legumes and other forbs

Under appropriate environmental conditions, and depending on their proportion in mixed pastures, legumes can capture 40 to 120 pounds of N from the atmosphere per acre-year. Inoculation of legume seed with the appropriate bacteria is essential for N fixation

(see chapter 4), unless these bacteria happen to be present in the soil (a risky assumption).

Legumes perform better in soils with neutral or slightly higher pH than in acidic conditions. They also require high amounts of P and K, as uptake of these macronutrients by legumes often exceeds that by cool-season grasses. In addition, soils must supply adequate boron (B) and molybdenum (Mo), both of which are important for N fixation. Amending soils as necessary can increase N fixation by legumes (see chapter 3).

Legumes differ from grasses in several other ways:

- Legumes typically have higher crude protein levels, intake potential, and rates of digestibility (see chapter 11).
- Because they have more horizontally oriented leaves, legumes capture sunlight at lower leaf area density.
- Legumes have deeper roots.
- Legumes have higher forage calcium (Ca) and magnesium (Mg) content, which can reduce the incidence of grass tetany when legumes are incorporated into grass pastures (see chapter 12).
- In the case of alfalfa, the optimum temperature for growth is higher.
- With the exception of birdsfoot trefoil, sainfoin, and cicer milkvetch, legumes can induce bloat in ruminants. Including grasses in the pasture reduces this risk (see chapter 12).
- Some legume species, such as birdsfoot trefoil and red clover, can flower prolifically and reseed themselves even under moderately heavy defoliation pressure.

Like alfalfa and red clover, forage chicory is a tap-rooted, summer-active perennial. During vegetative stages of development, these species usually have higher nutritional value, including mineral concentrations, than grasses. Chicory has a low-growing rosette growth habit in winter. After the establishment year, it is capable of reproductive stem development during late spring and summer growth cycles. Defoliation management should be similar to that for alfalfa.

Brassica species and hybrids present an almost overwhelming variety of morphological characteristics and growth habits. They vary widely in the time needed to reach maximum production, the proportions of stems and edible roots in their total dry matter (DM), regrowth potential, and cold tolerance.

Spring-planted brassicas can supply forage by mid- to late summer. Short-season species (including forage turnip, forage rape, stemless kale, forage radish, and Chinese cabbage x turnip hybrid) offer more summer regrowth potential than long-season species, such as swedes (fodder beets) and stemmed kale. For brassicas with summer regrowth potential, leave at least 3 to 4

inches (ideally 6 to 10 inches) of residual stubble and leaf area to support rapid recovery.

Summer-seeded brassicas can be used to extend late-fall and early-winter grazing. With the exception of summer-planted winter rape and some kales, most brassicas do not survive the winter in the northern United States. Where the crop is not expected to regrow in fall or survive the winter, fall grazing management can focus on capturing as much forage as possible without regard for residual stubble.

All brassicas have leaves with extremely high digestibility, compared to forage grasses and legumes. Swedes and turnips also develop edible roots. Digestibility of brassica forage decreases much less with plant maturity than that of grasses and legumes. It also is retained longer into winter.

Forage fiber concentrations of brassicas are much lower than those of grasses and legumes. This low fiber concentration can impair proper rumen function, making grazing animals sick, if brassicas exceed 75 percent of dietary DM. You can meet grazing animals' fiber requirements by supplying a source of fiber such as hay or inter-seeding brassicas with grasses.

For more information

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Appendix Chapter 6

Creation and Management of Soil Organic Matter in Inland PNW Pastures

Steve Fransen and Rich Koenig¹

One of the most powerful tools we have available to use in Inland PNW pasture management is the simple soil test. These are not costly at testing laboratories in the region and have been discussed in greater detail in other chapters in this Pasture Calendar. One of the most important tests is often the most overlooked: *soil organic matter* (SOM). Often on the soil test report, SOM is shown as a percent “OM”. Soil organic matter plays many vital roles in the soils of PNW forages and pasture systems. This chapter highlights how SOM is produced, its composition, some of those key soil-plant relationships, and what options we have to increase this valuable resource.

Soil organic matter starts off as fresh organic materials, composed of different plant and animal parts that decompose through microbial processes to soil organic matter residues. Think in terms that organic material does not have long-term stability while organic matter is stable in soils for a long time. The commonly accepted ratio of organic material : organic matter is about 10:1, which means it takes a great deal of above and below ground organic material to produce a small amount of SOM. Plant residues are the major source of material from shedding roots, dead stems and leaves, and/or from manures and composts. Thus, SOM is largely composed of carbon, and soils have been estimated to have twice as much carbon stored as what is stored in the atmosphere. Animals contributing to SOM are largely insects, nematodes, earthworms, and other soil microorganisms, such as fungi and bacteria. Color of SOM often reveals a great deal about its age and how active it is to contribute to the living ecosystem. A “average” SOM residue composition is about: 20 - 50 % cellulose; 10 - 28 % hemicellulose; 10 - 30 % lignin; 1 - 5% simple sugars; 1 - 8 % fats and waxes; and 1 - 15 % proteins. During decomposition or oxidation of SOM, the simple sugars are used first, followed by proteins and hemicellulose, then cellulose, and finally lignin. Waxes/fats are decomposed last. From these ratios, it is easy to recognize the contribution of shedding plant roots to the distribution and content of average SOM. In pastures, SOM is vitally important to supply water and nutrients to monoculture stands or mixtures of different plants.

Why is SOM important? Nutrients, soil structure, and soil water storage.

Nutrients. SOM is a slow-release form of plant nutrients and serves as a matrix to retain and exchange nutrients for plants. Soil organic matter decomposition is both a fast and slow process, taking up to months / years to complete. Simply, the carbon (sugars) + oxygen is converted to CO₂ + water. Because there are actively growing plants in the pastures during the grazing season (Growth Periods 2a, 2b, 3, 5a, 5b, 6a, 6b, 7, 8a, and 8b, see Introduction Chapters 6 and 8) the carbon dioxide being lost should be recaptured by plant leaves in the photosynthesis process. This recycling of CO₂ minimizes losses back to the atmosphere and is important for continued pasture plant regrowth and yield for grazing. Decomposing nitrogen compounds start with proteins converted back to building block, amino acids, through ammonification, and finally to ammonia through ammonification. Ammonia can be converted to nitrite and then to nitrate, which is the major nitrogen source taken up by pasture grasses. As organic materials decompose, they also release substantial phosphorus, potassium, sulfur and micronutrients, all of which are required by plants to produce a healthy and productive pasture stand.

Tillage can reduce SOM through increased oxidation (decomposition), while increases in SOM will occur under good grazing management with desirable perennial forage / pasture species. Pastures have the essence of time for accumulation of SOM through pasture plant root generation and shedding. Above ground biomass accumulation is available for grazing using best management practices under a suitable grazing system, as has been described in another chapter. Overgrazing, which has been discussed in several chapters, is the process of frequent and severe consumption of above-ground forage, often without a rest period for recovery. This will have a long-term impact on negative accumulation of SOM. We have observed in overgrazed irrigated pastures during Calendar periods 5a, 5b, 6a and 6b (spring flush), no white roots where there should be a complete upper soil profile of white roots, resulting in exceedingly small amounts of grazable leaf and stem, with little significant regrowth the rest of the grazing season. The building of SOM depends on an active root production – root shedding cycle. The root shedding cycle starts in Growth Period 7 then progresses through Period 10 during the growing season. The next period of root shedding occurs during Period 4, winter dormancy. Perennial grassland pastures have the greatest potential to increase SOM compared to forestry and annual plant

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production systems because of root shedding that occurs twice per year with grasses and the lack of annual tillage operations.

Soil structure. SOM is also key to holding soil particles together into aggregates, enhancing aeration (gas exchange) and water holding capacity in soils. Typically, PNW forage and pasture systems are based on perennial grasses and legumes, which greatly limit tillage operations. This provides opportunities for long-term production and recycling of roots, stems and leaf residues, but can also lead to compaction. An important inverse relationship exists between SOM and soil bulk density, which is an important attribute in pastures that are occasionally or continually overgrazed and prone to compaction.

Soil water storage. SOM enhances soil water holding capacity. Acting like a sponge, SOM can absorb and release water for plants. Most of the water held by soil against the pull of gravity is available to plant roots. Soil water holding capacity is influenced by the texture of the soil, which is based on the percentage of sand, silt, and clay in soil. Sandy soils have the largest particles and clays the smallest. The large particles in sandy soils don't retain water very well, so water drains through them rapidly, leaving little for plants. Fine-textured (silt and clay-dominated soils) retain water in small pores between these smaller particles.

SOM will retain up to 100 times its weight in water compared to soil mineral particles, which may retain less than half their weight. The effect of SOM on water retention is two-fold: first the direct effect of water-holding by porous organic particles and second by enhancing soil structure and the formation of small aggregates with pore spaces that effectively serve as reservoirs to store soil water. The amount of retained water depends on numerous factors, but in perennial pastures in the PNW, it mainly depends on how producers manage pastures and avoid overgrazing.

Water storage is of prime importance for SOM in perennial pasture systems. One can estimate how much plant-available water can be stored by different soil textures and SOM contents. Available water capacity is the moisture available to plants between field capacity and wilting point. In all soil textures, SOM will increase if the pastures have an opportunity to produce above ground biomass and roots that will be shed. Sandy soils have greater potential for SOM accumulation than clayey soils, but sandy soils inherently store less water in these larger pores than clayey soils. One, often-quoted relationship is that for every 1 % increase in SOM water storage capacity increases about 20,000 gallons per acre (1,870,790 l/ha). There are several assumptions that go into this value, such as soil bulk density and SOM holds 10X its weight in water, but for perennial pastures producers in the Inland region, which seems

like a fair value. We have highlighted for nearly every MLRA in the Calendar, an average SOM value. Through use of the Calendar and the supporting educational materials adapted by producers in this region, if SOM were increased often from less than 1 % - 1.5 % to 3 %, that would represent tens of thousands of gallons of additional water holding capacity per acre for pasture Growth Periods 7 and 8a, 8b. This could prevent some dryland pastures from transitioning to Growth Periods 9 or 10 and reduce hay feeding season while avoiding overgrazing.

Regardless of whether Inland pastures are irrigated or dryland, traditional summer climate patterns lead to very dry conditions. For pastures to continue producing past the spring peak flush (Growth Periods 6a and 6b) and during summer Growth Periods 7, 8a and 8b, reserve soil water in the rooting zone is essential. This soil moisture storage is enhanced by SOM. Keeping the rooting systems hydrated also allows for nutrient exchange through soil aggregates when, during the summer growth periods, pasture plants are shedding roots.

The current SOM in PNW pastures will vary by the pasture species and past grazing management practices. Overall, the better management imposed with more productive forage species, the greater the SOM. Within the Calendar, we have discussed average SOM contents within different MLRA's to highlight where some producers have been. With overgrazing, plants don't have the opportunity to increase SOM so decreases in SOM can result.

Various agronomic management practices can increase or decrease the accumulation and decomposition of SOM in perennial Inland pastures. To increase the speed of SOM decomposition in perennial pastures, use of an aerator (machine pulled by a tractor with spikes about six - eight inches (15 - 20 cm) long) during late fall / winter or summer, when perennial grassland roots are shedding, is recommended (Appendix Chapter 3). We have highlighted several MLRA's where soils are often acidic (MLRA 6 and 9). Liming will adjust the pH of the soil, but lime will also improve the health and productivity of the pasture plants. The indirect effect is increased SOM through greater plant biomass. Fertilizer application that increases pasture plant productivity will also increase SOM, however, like liming, the pasture manager should avoid overgrazing so plants accumulate in the SOM bank account.

The 2015 Food and Agriculture Organization, Status of the World's Soil Resources, Main Report, is focused on all forms of worldwide soil threats. Soil erosion is the major soil function of concern as impacted through bare soils by cultivation, deforestation, drought, and overgrazing. Soil compaction is directly impacted by overgrazing and heavy equipment. Soil texture and SOM can mitigate some compaction through increased soil stability, water

infiltration, water storage, and carbon sequestration through root shedding.

Soil organic matter is but one tool to monitor in perennial pastures; however, the short and long-term impact of this decaying residue is vitally important to the health of soils, plants, and the grazers. Slight changes in management can greatly impact both the sustainability and lifestyle of producers residing in the Inland region. Continue to monitor SOM on the soil test results with the goal of increasing that value as season's progress!

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Appendix Chapter 7

Grazing Behavior and Direct Effect of Grazing

Carmen Willmore and Glenn Shewmaker¹

Introduction

Animal grazing behavior has ecological impacts on the forage resource they are utilizing. Therefore, it is important to understand how grazing behaviors differ between livestock species as well as their impacts on forage resources being used. A basic understanding of grazing behavior gives managers knowledge and insights how animals might interact within a forage resource and with each another. Forage resources may be grazed differently as well as different livestock species are better suited for certain resources.

Grazing Livestock

Cattle, goats, sheep, and horses are typical grazing species. Cattle, goats and sheep are all ruminants and can effectively utilize forage species for their sustenance because of the function of their rumen. Horses are hind gut fermenters and are also able to utilize forage for sustenance through the function of their stomach and colon for fermentation. Wildlife species that are commonly considered grazers in the Pacific Northwest are elk, deer, moose, pronghorn and bighorn sheep. Their interaction with forage and pasture species is less well documented but does have impact on many forage resources, specifically during the fall and winter months as these animals move closer to lower areas where hay and pastures are readily available.

The basics of grazing consist of livestock searching and choosing forage to consume and then eating the forage. Differences in the forage consumed by a certain livestock species depend on the differences in their digestive systems and maintenance requirements. For instance, sheep and goats usually select for higher quality forages than cattle because their daily requirements are higher than that of cattle.

Grazing Height

When forage is tall enough cattle will eat by wrapping their tongue around the plant and pulling it into their mouth. With shorter forage they will grip the forage between the upper and lower molars and between their lower incisors and the upper dental pad and sever the forage from the plant with a backward jerk of their head. On the other hand, sheep and goats can be more

selective when grazing because of their smaller mouth parts which they can use to bring forage into their mouth and then bite it. This allows them to graze closer to the ground than cattle. Goats more than sheep are known as “mixed-feeding opportunists”. This is because they are faster to adapt to seasonal and geographical variations than are cattle and sheep. For this reason, they have been used with success for targeted grazing against a variety of invasive weeds. In a pasture setting goats are also known to forage at an elevated height whereas cattle and sheep keep their heads “down” when foraging. The design of a cow’s mouth parts, lips, teeth and jaw prevent the cow from grazing closer than 2 inches (5 cm) from the ground. See Appendix Chapter 11 for more information on the effects of forage abundance or plant height on forage dry matter intake, bite size and rate, and livestock production.

Overgrazing can occur with any grazing species but happens more severely with selective grazers such as horse, sheep and goats. Because of their nimbler mouth parts, they can select desirable species over those that are less desirable, causing overgrazing. Cattle will also do this but tend to be less selective when grazing on pasture. In pastures that are continuously grazed this can create areas of extremely low statured plants that have been over-selected and very mature plants left untouched decreasing the quality of the pasture.

Grazing Time

Livestock activity is divided between grazing, ruminating and resting. In general cattle, sheep and goats spend on average 9 hours/day grazing, but this time can vary from as little as 7 hours to as many as 12 hours grazing. Typically, livestock have one major grazing event first thing in the morning that will usually last about 3 hours, this is followed by a few hours of rumination and then shorter grazing periods through the midday with another major grazing event in the evening followed by resting and ruminating over night with a few short grazing during late evening. The time an individual animal spends grazing will also be influenced by stocking rate, stocking density and the amount of available forage. In management intensive grazing systems cattle will be grazing small areas for shorter time periods which will influence the average grazing time. In areas of lower quality forage this will increase grazing time so animals will be able to consume enough to meet their requirements. Pastures with higher quality forage may see shorter grazing length times as animals can meet their requirements in a shorter time period. However, this system should be managed

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very carefully to ensure that the grazers are still able to meet their daily maintenance and growth requirements.

Grazing Location and duration of grazing

Many things can impact grazing location. In a pasture with uniform forage quality and quantity, foragers can remember where they have previously grazed for up to 8 hours and cattle are rarely observed grazing in the same location for more than 2 days at time. In pastures that are less uniform and contain areas of higher and lower quality, cattle may not return to lower quality sections for upwards of 21 days. The same can be said for pastures that have been overgrazed and contain little forage in certain areas sheep, goats and cattle have reference memory and can remember locations of lower forage availability for up to 20 days.

When pastures are overgrazed, the time spent grazing will increase as livestock search for nutritious forage. During the summer months when forages are going through root shedding and slowed growth, it is important to decrease grazing intensity so as not to damage the pasture resource. Make sure to have adequate forage resources through the Calendar designated by Growth Periods 8a, 8b, 9 and 10 so that overgrazing does not damage the future of your resource. Also ensure that irrigated pastures are properly fertilized and irrigated during the growing season to manage this critical time to maximize the potential of the pasture.

Forage demand of livestock species

The amount of forage needed for a set of animals will depend on the number of animals in the pasture as well as their size and production status. Livestock need to consume a certain percentage of their average body weight daily to meet their maintenance requirements (Table 1). During certain physiological phases of their life such as pregnancy, lactation, and breeding their requirements are higher than average. It is important to keep this in mind as you select your breeding season and when the subsequent season of calving, lambing or kidding followed by lactation may be for your female livestock. In a pasture-based system it is best to set your animals up for success by planning when their highest nutritional needs are with the spring flush of your pasture. For instance, if the majority of forage species in your pasture are at their highest nutrient level in May-June you should plan for parturition to occur in late March as the highest nutrient requirement for that dam will be in early lactation which will occur 5 to 7 weeks after birth of their offspring. A similar growth period is observed in the fall. As plants come out of summer dormancy and enter steady fall regrowth (2a and 2b) near the end of September increasing the quality of forage in these fall months. This is another typically period for fall calving herds as well as weaning of calves and feeding of stocker

Table 1. Daily Dry Matter demand (by % of body weight) for different livestock species

Species	Body Weight %	Dry Matter Demand per Day
Cattle	2-2.5	Avg. Wt. 1200 lbs. at 2.5% = 30 lbs.
Sheep	2.5 – 4	Avg. Wt. 170 lbs. at 3% = 5.1 lbs.
Goat	5	Avg. Wt. 150 lbs. at 5% = 7.5 lbs.
Horse	2.5 -3	Avg. Wt. 1200 lbs. at 2.5% = 30 lbs.

calves. Matching the peak quality of your forage with the peak of your livestock needs is vital in matching your animal needs to the forage resources.

Forage Preference

Cattle, sheep and goats have preferences for certain forage species. In general cattle prefer grass species over forbs and legumes, whereas goats prefer forbs, browse and legumes over grasses. Sheep fall in the middle where they will consume both with minimal aversions. As the season change, so does the palatability of many grasses and legumes. A prime example of this would be tall fescue which is palatable to cattle during the early growing season and as stock-piled forage for use after frost, but during summer months has much reduced palatability.

Grazing animals select a variety of plants and plant parts to eat and prefer some and avoid others. Ruminant preferences or aversions are responses to physical and chemical senses of which touch, smell and taste are of greatest importance. Food preference is seldom a response to a single factor, but rather a combined response to several stimuli. We accept the theory that chemical, and some physical factors affect the positive feedback mechanism. The intake of food is determined by the complex interaction of pre- and post-absorptive factors. Those factors operating before the food leaves the mouth can be collectively referred to as palatability while those operating after this stage are referred to as post-ingestive. Cattle preference of eight, endophyte-free tall fescue cultivars was related to total nonstructural carbohydrate concentrations in the forage.

Plant maturity is the primary factor affecting palatability. Palatability declines with increasing plant maturity. Plant species is usually the next major factor affecting palatability. Within a plant maturity stage, for example, boot stage, of common irrigated or high rainfall pasture grasses, anecdotal analysis of palatability studies may rank from most to least palatable: perennial ryegrass > meadow bromegrass = meadow fescue => orchardgrass > timothy > smooth bromegrass > tall fescue. Among dryland grasses at the mature stage the palatability declines from: Russian wildrye = smooth bromegrass > crested wheatgrass > tall wheat grass and invasive annuals such as cheatgrass > medusahead wildrye = ventinata.

Optimizing timing of animal moves

Plants exhibit a daily cycle in their concentration of nonstructural carbohydrates (sugars, starch, and fructans). Sugars are produced during the day through photosynthesis. During the afternoon, plants can have a 15 percent higher concentration of sugars than in the morning, as well as lower neutral detergent fiber and higher yields. As animals sense these higher sugar concentrations in the afternoon, they graze for shorter periods of time, while increasing their bite size and bite rate. Generally, livestock grazing in temperate climates on continuously stocked pastures have longer afternoon grazing sessions. Grazing, ruminating, and idling times and patterns are presented in Figure 1 (Crane et al., 2010).

Pasture managers can impact grazing behavior by the timing of movement into new pastures or paddocks. Dairy and beef operations have benefited by allowing animals into new pastures or paddocks in the afternoon rather than in the morning. Cattle allowed into a new pasture at 7 a.m. will have to graze longer and still will not obtain as much energy as cattle allowed into a new pasture at 3 p.m. Furthermore, forage intake can be limited in the morning by higher concentrations of fiber, which result in greater rumen fill.

Mixed Grazing

Of the livestock species mentioned there are some that cohabitate more effectively in a pasture situation.

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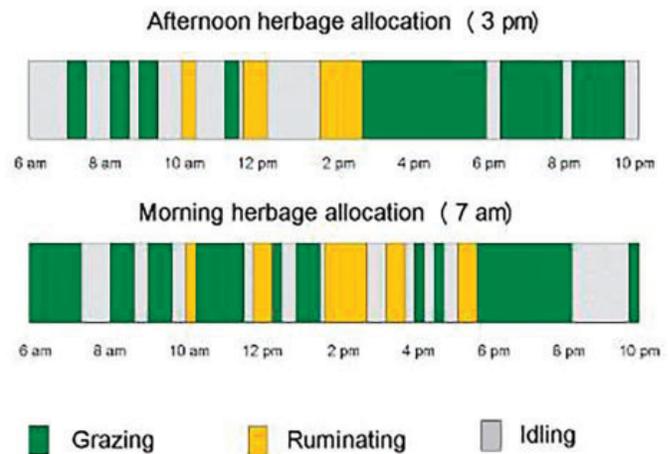


Figure 1. Grazing, ruminating, and idling time and pattern for cattle allowed into a new paddock at 3 p.m. or 7 a.m. (Graphic represents several studies adapted from Gregorini et al., 2006, *J. Anim. Sci.* 84:1943–1950.)

Cattle and sheep mixed grazing is one of the most common models and has benefits as cattle tend to graze at a higher level than sheep who prefer to graze lower as well as prefer legume species over grasses. Two species that are not recommended to graze together are horse and sheep as they both graze extremely low to the surface creating “wolfy” plants in ungrazed areas and overgrazing the more palatable plants.

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Appendix Chapter 8

Beneficial Pastures May Contain Hidden Hazards for Livestock

Scott Duggan¹

There are 654 million acres (2,646,644 km²) of pastureland in the United States and 16.2 million acres (64,750 km²) in the Pacific Northwest (PNW) region of Idaho, Utah, Oregon, and Washington providing valuable forage for livestock. Irrigated and dryland pastures provide livestock producers economical feed for livestock that convert forages into high quality food for humans. Unfortunately, beneficial pastures may harbor poisonous plants, weeds high in nitrates, and forages lacking in essential nutrients that cause sickness and death of livestock. Plant toxicity is a significant cause of economic loss to the livestock industry. It is estimated that 3 to 5% of the cattle, sheep and horses grazing pastureland in the western states ingest poisonous plants resulting in illness, poor rate of gain, birth defects, reproductive losses and even death. Drought and overgrazing of pastures and rangelands often correlate with livestock poisonings. To avoid poisoning of livestock, careful management of beneficial and toxic plants in pastures is advised.

Toxic Plants in Irrigated Pastures

Poison hemlock (*Conium maculatum*) is a toxic plant found in irrigated pastures. Poison hemlock is a member of the carrot family and may be mistaken for wild carrot, water parsnip and wild parsley. Poison hemlock grows 4 - 10 feet (1.2 - 3 m) tall, has irregular purple spots on hairless, green stems with a white, umbrella shaped flower. This is an introduced species that has spread throughout the Northwest and the U.S. by seed dispersal. Plants produce upwards of 30,000 seeds and can spread on water and wildlife. Poison hemlock spreads quickly in wet soils and may expand into fields with semi-dry soils. Poison hemlock can form tall hedgerows along waterways limiting access to rivers and streams. Walking through these hedgerows may result in respiratory difficulty due to inhalation of toxins.

All parts of poison hemlock are poisonous due to toxic alkaloids. Toxicity may vary depending on stage of growth, time of year, moisture, temperature, time of day, and geographical region. Immature leaves in the spring have increased toxicity. Livestock avoid hemlock as long as there is quality feed available. However, if the plant is baled into hay or growing among pasture grasses and accidentally ingested, it only takes a small amount to kill.

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Photo by Scott Duggan

Figure 1. *Conium maculatum*, Poison hemlock forming hedgerows along river.

Sheep may be poisoned by eating as little as 4 to 8 ounces (113 – 226 g) of green leaves. Cattle that ingest 10 to 16 ounces (283 – 454 g) may be negatively affected. Poison Hemlock is deadly to humans, all classes of livestock, and wildlife. Skeletal deformities and cleft palate affect offspring when livestock ingest sub-lethal amounts.

Due to its similar appearance and toxicity, poison hemlock is sometimes confused with western waterhemlock (*Cicuta douglasii*) and bulb-bearing waterhemlock (*Cicuta bulbifera*). Poison hemlock is in the same family, but is a separate and distinct species. Alternative names for western and bulb-bearing waterhemlock include cowbane, wild parsnip, and beaver poison. This wetland plant grows along rivers and streams at the waterline with the roots submerged in water. Western and bulb-bearing hemlock thrives throughout the Western United States and Canada.

Water hemlock grows 2 - 4 feet (60 – 120 cm) tall with light green, hollow stems. The leaves are dark green, alternatively arranged and narrow-toothed. Hemlock flowers are white and grouped in umbrella-shaped clusters. Waterhemlock reproduces from seed and vegetatively through overwintering root structures.

Western water hemlock is the most violently toxic, indigenous plant in North America. Toxic levels of cicutoxin are present in the thick, straw-colored sap contained in the tubers. Cicutoxin is also present in the leaves, stems, and immature seeds. The bulbous roots contain hollow chambers and contain the highest levels of cicutoxin. A two-ounce piece of root will kill a 1,400 pound (635 kg) cow. If the fleshy root is cut or broken



Photo by Scott Duggan

Figure 2. *Cicuta douglasii* Water hemlock with white flowers growing along irrigation canal.



Photo by Scott Duggan

Figure 3. *Cicuta douglasii* Western waterhemlock bulb

by livestock, it releases the yellowish liquid, potentially poisoning the water.

Fortunately, animals tend to avoid this plant when other forage is available. However, in early spring when the grass is short, hemlock grows among the grass in riparian areas and may be accidentally ingested. Even when it is mature and dried out, waterhemlock possesses toxins capable of killing livestock. Symptoms of waterhemlock and poison hemlock are similar and may include the following:

- Nervousness and dilation of the pupils.
- Increased pulse and respiration rate.
- Excessive salivation and frothing.
- Muscle tremors and convulsions.

- Death may occur in 15 minutes after a lethal dose is consumed.

Elimination of hemlock plants from pastures is critical. Hand pulling is effective when the soil is moist. Be careful to pull the entire plant including all of the roots, dispose in a garbage bag, and haul to the proper waste management facility. Wear appropriate gloves, long sleeves and eye protection as contact dermatitis is possible. Do not contact the plant, especially the roots, with bare hands and then touch the eyes or mouth. Do not burn as toxins may become airborne.

Several types of herbicides are effective in control of hemlock. Use caution when spraying as there are restrictions for applying herbicides near waterways. Always read the label before application of herbicides. When hemlock is sprayed with herbicides, an increase in palatability occurs. Keep animals away from treated plants for 3 weeks after spraying. For more information on the correct herbicide consult your local county weed board or Extension office. Due to their high toxicity, caution is paramount when dealing with poison and water hemlock. Additional information on western waterhemlock is published in *Western Waterhemlock in the Pacific Northwest* PNW109.

In addition to the aforementioned hemlock plants, there are additional plants that grow in pastures capable of poisoning livestock. To learn about these plants visit the Oregon State University Extension website at: <https://extension.oregonstate.edu/collection/poisonous-plants-commonly-found-pastures>.

Plants Poisonous to Livestock in Dryland Range Pasture

Irrigated pastures are not unique in harboring poisonous plants as dryland pasture contains plants poisonous to livestock. Two range plants especially damaging to livestock include larkspur and lupine. Larkspur is an erect, herbaceous plant with dark blue flowers that grows in mountain rangelands. Larkspur contains toxic alkaloids that impair the nervous system resulting in muscle weakness, inability to stand, respiratory paralysis, bloat and death in cattle. Sheep and goats are resistant to the toxic alkaloids in larkspur. Cattle deaths from ingestion of larkspur and the inability to graze pastures infested with larkspur is a significant financial loss for ranchers in the Intermountain West. Death losses of 4 - 15 % have been documented in Utah, Colorado, and Montana.

Larkspur is categorized into three types according to height and growing conditions. Tall larkspurs (*Delphinium barbeyi*, *D. occidentale*), low larkspurs (*D. nelsonii*), and the plains larkspurs (*D. geyeri*). Larkspurs initiate growth early in the spring before other forages. The highest level of toxicity occurs in the immature stage of growth. Fortunately, immature plants are not preferred at this stage

of development. With plant maturity, larkspur becomes more palatable to cattle and the toxicity levels drop, with the exception of the seedpods. Immature plants and seeds have the highest concentrations of toxic alkaloids. Larkspur baled up in hay is poisonous as toxin levels increase when the plant dries.

It is during the flowering period when plants are palatable and toxicity levels remain moderate that a majority of the poisonings occur. Heifers and cattle less than two years of age are more susceptible to larkspur poisoning. Horses are moderately susceptible to poisoning, but avoid larkspur unless there is no other forage available. Symptoms from ingestion of the toxic alkaloids contained in larkspur include:

- Excess salivation.
- Straddled stance and arched back.
- Inability to stand due to muscle fatigue and paralysis.
- Paralysis of the diaphragm and digestive tract.
- Difficulty breathing.
- Bloat and death within 3 - 4 hours.

Rangelands containing larkspur need to be carefully managed to prevent economic losses. When grazing land with heavy infestations of larkspur, managing cattle herds according to sex and age is beneficial. Herbicide treatments are beneficial in areas where it is economically feasible. Additional information on larkspur is found in the Utah State University publication, *Reducing Losses Due to Tall Larkspur Poisoning* www.behave.net.

Similar to larkspur, lupine is known for its beautiful flowers and toxicity to livestock, especially sheep. Lupine (*Lupinus* spp.) is commonly found in the foothills and mountains of the West. There are over 100 species of lupine in North America and not all species are poisonous to livestock. Species of lupine causing toxicity in sheep include:

- Silvery lupine (*L. argenteus*)
- Velvet lupine (*L. leucophyllus*)
- Big bend lupine (*L. leucopsis*)
- Silky lupine (*L. sericeus*)

Species of lupine causing toxicity in cattle include:

- Tailcup lupine (*L. caudatus*)
- Broad leaf lupine (*L. latifolius*)
- Spurred lupine (*L. laxiflorus*)
- Silky lupine (*L. sericeus*)
- Yellow lupine (*L. sulphureus*)
- Lunara lupine (*L. formosus*)

In addition to causing illness and death, lupines cause birth defects in cattle. Cows that ingest lupine between 40 and 100 days of pregnancy risk developing deformed

calves. Known as “crooked calf disease”, calves are born with cleft palates, crooked legs and distorted spines. Cows with calves that are severely deformed cannot deliver their calves without assistance.

All parts of lupine are poisonous and immature plants in the spring season contain higher levels of toxins than mature plants. Lupine is least toxic in the pre-flowering stage prior to formation of the seed containing pods. When adequate forage is available in early spring cattle may avoid ingesting lupine or ingest small amounts at non-toxic levels. However, low amounts consistently eaten over a period of 3-5 days will accumulate toxins and induce poisoning in livestock.

Severity of poisoning is the result of the amount ingested, stage of plant maturity, and time of year. Sheep arrive at toxic levels quickly, needing to consume only four ounces of plant matter to reach a lethal dose. Cattle ingesting one pound (454 g) of lupine arrive at toxic levels. If seeds are ingested, toxic levels will quickly rise as seeds contain the highest levels of toxic alkaloids. Spikes in lupine poisonings often occur in late summer and early fall when sheep and cattle are trailed home from summer range through meadows containing flowering lupine with toxic seeds.



Lupine on rangeland in Idaho. Photo by Carmen Willmore

Symptoms of lupine poisoning are similar to larkspur poisoning and include:

- Nervousness and excitability.
- Excessive salivation and frothing.
- Difficulty breathing and loss of muscle control.
- Depression, lethargy, and unwillingness to move.
- Blindness and convulsions.
- Coma and death.

Careful management of dryland pasture and range is necessary or significant livestock losses may occur. Larkspur and lupine can be controlled with herbicides if the area is of manageable size. In most areas of the West, rangeland is vast and herbicide treatments are not

economically feasible. Ranchers need to find alternative methods of grazing management in order to minimize the chances of livestock poisoning. Rangeland managers recommend the following livestock management practices.

- Identify poisonous plants and the symptoms of poisoning in livestock.
- Understand toxicity levels in plants and identify time periods when plants are the least toxic.
- Graze areas when toxicity levels are low and restrict areas when plants are likely to cause poisoning.
- Only graze areas with adequate forage.
- Monitor livestock and range area closely as environmental conditions may alter toxicity levels in plants.
- Do not overgraze and force livestock to ingest plants they normally avoid.

In addition to the aforementioned toxic plants, there are additional poisonous plants that dryland pasture managers need to be aware of when farming dryland acres. An excellent resource is Chapter 12 of *Pasture and Grazing Management in the Northwest* (Cash et al., 2010). See table 12.1 (page 124).

Grass Tetany or “grass staggers”

Grass tetany is a metabolic disorder caused by low magnesium levels in the blood. Rapidly growing, immature grasses and cereal grains typically contain low magnesium levels and high potassium concentrations. Magnesium is an essential nutrient critical for bone growth, muscular contraction, and nervous system function. Potassium levels above 3% reduces the absorption of magnesium in ruminants and in the plant. Animals cannot store magnesium and need a continuous supply of this essential element. Livestock prone to grass tetany include cows and ewes in late gestation or heavy lactation. Steers, dry cows, and heifers are more tolerant of low magnesium levels in forages. Horses may contract this disorder, but it is rare.

The spring season is known for cool temperatures, cloudy skies, and cool soils. Cool-season grasses growing this time of year often exhibit low magnesium levels, especially if the pasture was overgrazed prior to the spring season. Fall pastures may also be low in magnesium if there is fast regrowth of cool-season grasses after the heat of summer. A forage test for mineral content provides magnesium levels and a ratio of potassium levels in relation to magnesium and calcium. Ratios in excess of 2.2 potassium to calcium and magnesium indicate risk of grass tetany.

Additional forages susceptible to low magnesium levels include crested wheatgrass, bromegrass, bluegrass, timothy, wheat, rye, and oats. Incidence of grass tetany

is reduced when legumes are part of the pasture as this forage plant contains twice the magnesium as grasses.

Livestock low in magnesium exhibit the following symptoms:

- Hyper-excitability and restlessness.
- Unsteadiness and lack of coordination.
- Animals may become aggressive.
- Frequent urination.
- Head and neck tremors.
- Abnormal gait.
- Getting up and down repeatedly.
- Convulsions and death.

If livestock exhibit symptoms of having grass tetany, call a veterinarian immediately as there is a very short time period available to save the animal. A sterile solution containing magnesium and calcium needs to be administered intravenously if the animal is to be saved. Recovery is swift when intervention occurs in the initial stages of the disorder.

Strategies for prevention of this disease include:

- Provide a magnesium supplement ensuring every animal will receive 1 - 2 ounces (28.3 – 56.7 g) of magnesium oxide per day. Feed 30 days before spring grazing and for 30 days after the initiation of spring grazing.
- Cull animals that develop grass tetany as they are likely to develop it in the future.
- Seed legumes in grass pastures.
- Do not over fertilize pastures with nitrogen (N) and potassium (K) fertilizers or heavy applications of manure.
- Avoid stressing animals.
- In pastures susceptible to low magnesium levels, graze steers, heifers, and stocker calves that are less likely to develop grass tetany.
- Avoid grazing immature grasses less than 4 - 6 inches (10 – 15 cm) tall with lactating cows and ewes.

For more information and management practices for dealing with grass tetany consult *Nutrient Management for Pastures: Western Oregon and Western Washington* (EM 9224).

Milk Fever

Hypocalcemia or milk fever is a metabolic disorder that arises in cows, ewes, and does prepartum or postpartum. This disorder is initiated by increased calcium requirements for milk production and a shortage of calcium in rapidly growing forages. Similar to grass tetany, milk fever materializes in the spring season on lush pastures.

This potentially fatal disease occurs when the body is unable to maintain appropriate levels of calcium in the bloodstream. Symptoms include dystocia, fatigue, still-born calves, muscle weakness, loss of appetite, coma and sudden death. Strategies for prevention of milk fever include:

- Feed a balanced mineral supplement with correct calcium-phosphorus ratio.
- Avoid stressing animals.
- Cull females with recurrent milk fever.
- Incorporate legumes in pastures as legumes contain higher levels of calcium.
- Maintain a healthy body condition score.
- Test forages for calcium levels.

Identification of the symptoms and quick intervention increases the survival rate. There are three stages to this metabolic disorder. See table below for a description of symptoms.

Table 1. Three Stages of Milk Fever

Clinical Stage	Symptoms
Stage 1	Lack of muscle coordination, loss of appetite, nervousness, weakness, shuffling hind feet
Stage 2	Lethargy, depression, dry muzzle, rapid heart rate, staggering, decrease in temperature
Stage 3	Inability to stand, rapid breathing, loss of consciousness, coma & death

When detected in the initial stage, supplementation with feed that is high in calcium may solve the issue. If the animal has progressed from stage 1 to 3, the animal may die without a calcium solution injected intravenously. When symptoms are first observed, consult a licensed veterinarian for assistance.

Nitrate Poisoning

Plants and animals require nitrogen for growth and maintenance. Plants uptake nitrogen from the soil in the form of nitrate. In normal growing conditions, plants rapidly convert nitrate to amino acids and ultimately proteins for growth. In times of temperature, drought, or frost stress a decrease in plant growth occurs and nitrates can accumulate in the plant. Animals that consume plants with toxic levels of nitrates become ill and without treatment die within a few hours.

In ruminant animals, digestive processes convert plant nitrates to nitrites in the rumen. Rumen microbes turn nitrites to ammonia. Microbes utilize ammonia to make amino acids and protein for growth and maintenance. Consumption of toxic levels of nitrates overwhelm digestive microbes resulting in nitrites accumulating in the rumen. Excess nitrites are absorbed into the bloodstream

combining with oxygen carrying hemoglobin. Nitrites combined with hemoglobin form methemoglobin, which is incapable of transporting oxygen. Without oxygen, the blood turns a bluish/chocolate brown color and the animal suffocates and dies. This process happens quickly and ranchers have sustained catastrophic losses from one feeding of high nitrate hay or pasture. Symptoms of nitrate poisoning include:

- Labored breathing.
- Increased heart and respiratory rate.
- Frothing at the mouth.
- Frequent urination.
- Diarrhea.
- Lack of coordination and weakness.
- Collapse, convulsions, and death usually follow within 30 minutes of the onset of symptoms.

Upon identifying nitrate-poisoning symptoms, call a veterinarian and separate animal from the potentially toxic forage. If caught in the initial stages, administering a 4% solution of methylene blue injected intravenously may prevent death. A rate of 100 cc per 1,000 lb (454 kg) of body weight is recommended and should only be performed by a licensed veterinarian.

Cattle are most susceptible to nitrate poisoning followed by sheep and goats. Horses tolerate higher levels of nitrates as they are hindgut fermenters. Livestock producers need to be aware of environmental situations that cause plant stress and accumulation of nitrates. Conditions that cause nitrate accumulation include:

- Drought.
- Frost, hail, or extreme weather.
- Inadequate irrigation.
- Rainfall when nitrogen fertility is high.
- Disease.
- Successive days of cloudy weather that slows photosynthesis.

In addition to the environmental factors listed above, do not overgraze pastures as nitrates tend to accumulate in the lower stem of the plant. Nitrate levels are typically higher in immature forages than mature forages. Be aware that certain plants are nitrate accumulators. See table 2 for a list of plants.

In summer forages, weeds and non-crop plants may be high in nitrate accumulation. Working corrals may contain high nitrate weeds. Cattle gathered from range or pastures and temporarily placed in corrals are more inclined to eat weeds than cattle on range or pasture where adequate forage is available. Table 3 provides guidelines for determining the safety or toxicity of forages, weeds and non-crop plants.

Table 2. Nitrate accumulators classified crops, weeds, and vegetables

Crops	Weeds	Vegetables
Alfalfa	Bindweed	Beets
Barley	Bull thistle	Celery Cucumbers
Canola	Canada thistle Fiddleneck	Kale
Corn	Dock Fireweed	Lettuce
Fescue	Johnson grass Kochia	Parsnips Radishes
Flax	Lamb's quarters Mustard	Spinach
Millet	Nightshade Pigweed	Squash
Oats Orchardgrass Rye	Russian thistle	Swiss chard Turnips
Sorghum Soybean		
Sweet clover Wheat		

Sourced from: *Nitrate Toxicity in Beef Cattle*. OSU Beef Cattle Library

Table 3. Nitrate-nitrogen and nitrate level categories toxicity ratings and comments

NO ₃ -N ppm	NO ₃ ppm	Rating	Comments
0 to 564	0 to 2,500	Safe	Considered safe in most circumstances
568 to 1,136	2,500 to 5,000	Generally safe	Safe when fed in balanced rations. Limit to 50% of ration dry matter for pregnant animals. Check water for nitrates.
1,136 to 3,409	5,000 to 15,000	Danger	Limit to 25% of ration dry matter. Feed with a balanced ration. May encounter production losses and reproductive problems.
3,409 to 7,500	15,000 and 33,000	Toxic	Do not feed free choice. Feed only less than 15% of dry matter in a total mixed ration.

Sourced from *Nitrate Poisoning in Ruminants* FS139E

Table 4. Examples of forages and plants that can accumulate prussic acid.

Plant Type	Examples
Grains, forage crops and grasses	Corn, flax, sorghum, sudangrass, arrow grass, velvet grass, white clover, Indian grass, birdsfoot trefoil, Johnsongrass
Trees	Apricot, peach, cherry, chokecherry, elderberry, apple, wild black cherry, pears, plums.

Adapted from *Prussic Acid Poisoning in Livestock* FS129E

Additionally, over application of fertilizers results in plant storage of nitrates. To prevent nitrate poisoning, it is important to test soils prior to applying fertilizer in order to prevent over fertilizing. Prior to grazing a pasture

that is potentially high in nitrates, harvest plant clippings and send to a lab for analysis. When buying hay, ask

for a forage test. If the farmer refuses, look elsewhere for hay to purchase as testing is the only way to know if a hay is high in nitrates. A forage test is considerably cheaper than the replacement cost of dead livestock. For more information, see *Nitrate Poisoning in Ruminants*, FS139E, and consult the local Extension office or your veterinarian. For information on forage and soil testing:

<https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/ec628.pdf>

Prussic Acid Poisoning

The sorghum family of plants produces excellent forage. However, these beneficial forages may become poisonous under stressful environmental conditions to include freezing temperatures and drought. High levels of hydrogen cyanide (HCN), also known as prussic acid, occur in the sorghum family of plants to include Sudangrass, Johnsongrass, forage sorghum, and grain sorghum. Rapidly growing, immature plants in the sorghum family contain toxic levels of HCN until the plants are at least 18 to 24 inches tall (45 – 60 cm). As the plants mature, the prussic acid decreases. Sudangrass generally has the least amount of cyanide production potential, while forage sorghums, grain sorghums, and Johnsongrass produce higher HCN concentrations. Additionally, plants grown in soil high in nitrogen and low in phosphorus and potassium will have higher concentrations of HCN.

Plants outside of the sorghum family that also produce HCN include corn, flax, white clover, velvet grass, birdsfoot trefoil, chokecherry, serviceberry and arrowgrass. The wilted leaves, stems, and pits of cherry trees, peaches, plums and apricots contain HCN and should not be available to grazing livestock and horses. Apple and pear tree seeds, leaves, and stems contain smaller amounts of prussic acid and require animals to eat large amounts to induce poisoning. Prussic acid forming plants are collectively referred to as cyanogenetic plants.

Animals have the ability to detoxify HCN and excrete it in the urine. Unfortunately, when animals consume toxic levels of HCN, it is rapidly absorbed into the blood stream and prevents oxygen from being absorbed at the cellular level. Animals become sick and die of suffocation within 30 - 45 minutes after ingesting forage. Ruminants animals are especially susceptible to prussic acid

poisoning as ruminant microbial fermentation releases HCN.

Symptoms of prussic acid poisoning in livestock include:

- Excessive salivation.
- Labored breathing.
- Foaming at the mouth.
- Increased rate of respiration.
- Twitching, spasms, convulsions, respiratory paralysis and death.

Do not mistake prussic acid symptoms for nitrate poisoning. Although symptoms are similar, prussic acid poisoning results in the blood turning bright, cherry red. In contrast, nitrate poisoning turns blood to a dark chocolate brown. Additionally, the tongue and eyes will turn blue with nitrate poisoning. If these symptoms are observed, contact a veterinarian immediately and remove the animal from the toxic forage.

To prevent prussic acid poisoning, the following management guidelines will reduce the risk of grazing plants in the sorghum family.

- Do not graze sudangrass, sudangrass hybrids, or sorghum until the plants are at least 18 - 24 inches (45 – 60 cm) tall.
- After a frost occurs, wait 7-10 days before turning out livestock.
- Feed livestock prior to grazing pastures to slow ingestion of forage.
- Beware of short, immature regrowth after grazing, light frost or drought.
- Choose plant varieties with low prussic acid content.
- New leaves and tillers have highest concentrations of HCN.

If a forage test reveals high prussic acid content, consider harvesting hay instead of grazing. The amount of HCN can be reduced by 50 % through curing the hay prior to baling. Ensiling the forage will also reduce prussic acid content. For more information see *Prussic Acid Poisoning in Livestock*, FS139E.

Table 5. Livestock tolerance to levels of prussic acid in feed (dry matter basis)

Prussic acid (HCN) ppm	Effect on livestock
Less than 500	Generally considered safe
From 500 to 750	Potential for toxicity exists. Forage should not be the sole source of feed.
Greater than 750	Dangerous and will cause death

Source: *Prussic Acid Poisoning in Livestock* FS129E

Pasture bloat in livestock

Frothy or pasture bloat is a digestive disorder that occurs in ruminant animals. Bloat is primarily observed in cattle but sheep and goats are also susceptible. The rumen is essentially a large fermentation vat of rumen fluid containing microorganisms and partially digested forage that break down plants and extract energy ruminants can utilize. A byproduct of fermentation is carbon dioxide and methane gas. Under normal conditions, elimination of these gassy byproducts from the rumen occurs when ruminants belch. When the release of gasses is impeded, the trapped gasses expand in the rumen causing bloat.

Livestock grazing legumes or lush pastures containing over 50 % legumes are at risk for bloat. Ruminants grazing high protein, low fiber cereal pastures are at risk, too. Frothy bloat transpires in pastures primarily due to over consumption of legumes in the vegetative and early bud stages, especially alfalfa and white clover. High protein legumes rapidly break down in the rumen releasing gasses into the foamy layer above the rumen fluid. Excess gas expands the foamy layer interfering with the release of gasses through the esophagus. As extra gasses buildup, the rumen expands creating pressure on the diaphragm, which interferes with lung function. Death from suffocation and heart failure is relatively fast occurring in 30 minutes to several hours. Symptoms of bloat in livestock include:

- Distended abdomen on the left side.
- Animal will appear distressed and in pain.
- A reluctance to move.
- Strain to urinate and defecate.
- Rapid breathing - mouth may be open with tongue protruding.
- Collapse and death.

Frothy bloat typically occurs in the spring and fall when livestock, accustomed to grazing on dry hay or rangeland, are released into lush pastures. Livestock hungry for green grass will rapidly consume large amounts of lush forage creating the potential for bloat. To minimize risk of bloat set out bloat blocks and have dry hay available when transitioning to lush pastures. Weather events such as heavy dew, rain or frost also contribute to cases of frothy bloat. The dew, rain and frost moisten the forage allowing cattle to ingest it quickly as opposed to dry forages. After a heavy dew, allow pasture to dry out before grazing. Wait seven days before grazing frost damaged plants.

When beginning symptoms of bloat are identified make certain dry hay and water is available. Encourage livestock to move as it helps alleviate trapped gasses. If symptoms continue to advance, immediately consult a veterinarian for assistance. Recommended methods for treating moderate to advanced bloat involves removing

the animal from the pasture, confining the animal, and passing a stomach tube into the rumen to relieve gas. Antifoaming agents administered through the tube may help alleviate the gas. In cases of severe bloat, a trocar and cannula punched through the left side of the animal into the rumen may relieve gassy bloat when a stomach tube has not worked. Only use the trocar in an emergency situation.

Practices for avoiding bloat include:

- Limit the time livestock spend on lush pasture for the first few weeks.
- Feed dry, low protein hay prior to turnout on green pasture.
- Do not make rapid feed transitions.
- Provide low protein hay free choice while grazing pastures.
- Provide daily supplement with anti-bloat product. Bloat protectants like poloxalene can be fed as blocks or mixed with grain.
- Check animals for bloat every two hours when beginning grazing.
- If an animal frequently shows signs of bloat, cull from herd as they become chronic bloaters.
- Include non-bloating legumes when seeding pastures.

Additional information on preventing pasture bloat is located in Chapter 12 of *Pasture and Grazing Management in the Northwest*. The Merck Veterinarian Manual is another good source at:

<https://www.merckvetmanual.com/digestive-system/diseases-of-the-ruminant-forestomach/bloat-in-ruminants>

Pasture Associated Laminitis

Laminitis is a painful, yet often preventable, systemic disease capable of afflicting all hoofed animals but primarily seen in horses. *Laminitis* is Latin for inflammation of the laminar structures of the equine foot. Horses with laminitis develop temporary or chronic lameness, or in severe cases, require euthanasia. Traditionally known by its common name *founder*, laminitis can affect all members of the equine family. Owners often use these words interchangeably, however; the terms laminitis and founder are technically different. Founder typically refers to a chronic condition involving rotation of the coffin bone resulting in separation from the hoof capsule. In slight to moderate cases, the hoof may develop a dish shape, a cleft at the coronary band and separation of the white line. In severe cases, the coffin bone rotates down through the sole of the hoof and the animal has to be euthanized. In contrast, laminitis is a term describing the initial stages of the disease involving inflammation and pain. With prompt and successful treatment, separation

of the coffin bone from the hoof capsule is prevented and the horse makes a complete recovery.

Pasture associated laminitis (PAL) occurs when horses consume excessive amounts of forage high in starches, simple sugars, and fructans. This group of carbohydrates are collectively known as nonstructural carbohydrates (NSC). Mature horses 8-18 years of age, overweight horses and ponies are the most susceptible. A primary reason pasture founder occurs is that modern species of cool season pasture grasses are selectively bred for high sugar content and low fiber content. These forages with higher sugar content have replaced low sugar, high fiber forages of the past. Consumption of these higher calorie forages combined with a lack of exercise causes obesity and laminitis.

Through photosynthesis, cool season grasses produce sugars plants use for growth and maintenance. In times of plant stress (e.g., drought) or cold temperatures in early spring and late autumn, plant growth slows reducing demand for sugar. Unused sugars convert to fructans that are stored in the base of the stem. The stored sugar increases palatability, inducing horses and ponies to eat excessive amounts of forage, creating a digestive imbalance. This imbalance creates toxins that are released into the bloodstream triggering inflammation in the soft tissues and a laminitis episode occurs. Symptoms include an enlarged, thickened, cresty neck at the topline that is hard to the touch rather than soft and pliable. Lameness, a bounding pulse in the digital artery, a distorted hoof shape, increased heart rate, a shortened stride and a reluctance to move are additional symptoms.

To prevent horses suffering from laminitis, pasture managers need to be mindful of factors that slow plant growth and increase storage of fructans:

- Cool nights and warm, sunny days.
- Inadequate fertilization of pasture causing nutritional stress in grasses.
- Frosted pastures.
- Young, vegetative (“lush”) grass leaves.
- Drought stress.

Relative fructan (sugar) levels in common pasture species.

Fructan level	Species
Highest 	Perennial ryegrass
	Kentucky bluegrass
	Bentgrass
	Timothy
	Tall fescue
	Orchardgrass
Lowest	Clovers and alfalfa

Sources: Downing and Gamroth, 2007; Fransen and Hudson, 2006; Holechek and Galt, 2004; Shewmaker et al., 2006; Volenec, 1986; Watts, 2008.

In addition, cool season grasses have variable amounts of fructans levels depending on the species. When seeding new pastures, choose grass species with lower fructan levels.

Additional management practices that help prevent laminitis in horses includes:

- Apply adequate (but not excessive) nutrients—especially N and K—to keep plants growing.
- Maintain plant height above minimum 3 - 4 inch (7.5 – 10 cm) heights and don't allow plants to go to seed.
- Introduce horses to lush pasture slowly over a several week period.
- Rotate pastures to avoid grazing immature plants high in fructans.
- Use grazing muzzles on horses predisposed to laminitis.
- Limit grazing to the early morning hours when sugar levels are lowest between 3 a.m. to 10 a.m. Plant sugars are higher after 10:00 a.m., peaking around 2 p.m., and remaining high into the evening hours.
- Use caution when grazing after a frost or drought.
- Do not allow horses to graze freshly cut grass stubble as sugars are stored in lower 3" of the plant.
- Reduce or eliminate feeding of high-carbohydrate grain or supplements.
- Test the carbohydrate levels and protein in hay and pasture. Balance the ration as needed.
- Maintain adequate exercise for the horse.

For additional information see the *Western Oregon and Washington Pasture Calendar PNW 699* or *Adams' Lameness in Horses*.

Photosensitivity in livestock and horses

Photosensitization is a serious skin, and in certain cases, liver condition that affects horses, sheep, goats and cattle. Livestock and horses consuming plants with phototoxic plant compounds may develop photosensitivity. These photodynamic agents react to sunlight in areas of the skin lacking pigment. Skin will become red, weepy and swollen and severe skin damage may occur. By providing shade and removing the animal from the forage, a full recovery is possible. However, if the plant toxins damage the liver, the chances for a full recovery are poor.

Photosensitivity is common in light colored and white-faced livestock and horses. Colored cattle with white patches like Herefords and Holsteins are especially susceptible. Photosensitization typically occurs during the spring and summer months, when animals are exposed to intense sunlight after a long winter. Abrupt feed changes from dry hay or pasture to lush, green pastures

increases chances for developing photosensitivity. Photosensitization differs from sunburn, as it does not require prolonged exposure to sunlight to materialize.

Areas of an animal that have less hair or pigmentation, such as the muzzle, around the eyes, vulva/anus and teats, are especially prone to photosensitization. The white areas on the legs and face are frequently the worst affected areas. Lesions may appear on the udder causing pain and irritation. The cow often refuses to allow the calf to nurse, adversely affecting the health of the calf. Redness in the eyes, swelling in the eyelids, scabs at the tips of the ears, along with skin irritation resembling sunburn is initially observed. Animals will also appear uncomfortable, reduce or stop grazing, lose weight and will seek shade. If the animal is not removed from sunlight, the condition progresses causing watery swellings under the skin, severe skin damage to include blisters, swelling, and death of the tissue, followed by sloughing of the skin. In severe cases, even pigmented areas may be affected and the animal may go into shock. In situations where the liver is permanently damaged, animals may die from malnutrition and infection.

There are two general types of photosensitivity problems, primary and secondary. Primary photosensitization develops when animals eat plants with unique photodynamic agents that react to ultraviolet light. Sunburn like conditions appear but the liver is not damaged. Plants causing primary photosensitivity include tall creeping buttercup, buckwheat, St. Johnswort, and spring parsley. Secondary photosensitization develops due to liver disease and is the most prevalent form in livestock. The liver is damaged from plant compounds to include pyrrolizidine alkaloids. When a damaged liver is unable to process phyloerythrin, a breakdown product of chlorophyll, toxic amounts build up in the blood, resulting in photosensitivity. Forage plants capable of causing secondary photosensitivity include alsike clover and perennial ryegrass.

Consult a veterinarian if symptoms of photosensitization are identified. It is important to determine if the liver is damaged. Move the animals off the pasture to separate them from the source of toxic plants and provide cool, shaded housing and fly control. If liver damage has not occurred, a full recovery is possible. For more information and a list of photosensitizing plants, an excellent resource is Chapter 12 of *Pasture and Grazing Management in the Northwest PNW 614*. See table 12.1 (page 124).

Endophyte Toxins in Tall Fescue and Perennial Ryegrass

Plants have developed a variety of ways to prosper and survive over millennia. To ensure their survival, plants have developed symbiotic relationships with a wide range of organisms to include fungi, insects, trees and bacteria. Plants can harbor chemical compounds that

make animals sick and die when grazing the plant. These toxins “train” animals to avoid the plant, ensuring future survival.

Forage and turf types of tall fescue and perennial ryegrass forage are examples of plants that have a mutually beneficial relationship with another organism. These forages harbor an endophyte fungus in the seed that provides the plant with increased growth, increased drought tolerance, and resistance to certain insects. In addition, endophyte fungi produce bioactive compounds that will sicken and in rare cases kill grazing animals in order to protect the plant. In return, the plant provides shelter and nutrients for the endophyte fungi. The endophyte is completely contained within the plant. Infected plants cannot infect other plants, the endophyte only moves through the seed.

Farmers planted tall fescue over large areas of the U.S. in the 1940's. It established easily, had good longevity, spread quickly, and tolerated drought. Initial enthusiasm for the new forage waned as livestock began losing weight, produced less milk, experienced reproductive problems and aborted calves. Additional symptoms include elevated temperatures, rough hair coat, low blood serum, reduced feed intake and excessive salivation. These symptoms are collectively referred to as fescue toxicity. Other fescue disorders include fescue foot and bovine fat necrosis. Horses, beef cattle, dairy cattle, sheep and deer are susceptible to endophyte toxicity.

In recent generations, researchers succeeded in developing new fescue varieties that negate the toxicity of this fungus. Endophyte free varieties are now available that keep the benefits of the endophyte containing varieties, but does not produce the toxins that harm livestock and horses.

Old varieties of fescue may persist in fields and pastures. When purchasing hay, it is important to forage test any fescue hay purchased as it may contain endophyte toxins. Endophyte infected forages can only be determined by sending a forage sample to a lab.

Another form of endophyte toxicity occurs in perennial ryegrass. Toxic alkaloids produced by endophyte infected plants cause poor animal performance. Known as ryegrass staggers, sheep, cattle, horses, farmed deer and llamas are susceptible to endophyte-produced toxins. Young animals are especially at risk of illness and in severe cases, death. Perennial ryegrass forage infected with the endophyte, *Epichloë festucae* var. *lolii* produce toxins that cause weight loss, increased temperature, incoordination, tremors, stiff gait and collapse. Animals suffering from fever will try to cool themselves by rolling in water and sometimes drown or injure themselves. These symptoms become more severe when the animal incurs stress.

Affected animals need to be moved immediately from the pasture and typically recover in 4 to 7 days if symptoms are discovered in the initial stages. The fungus

and the toxin occur mainly in the leaf sheaths close to the ground. Grazing infected pastures below 3 to 4 inches (7.5 – 10 cm) is likely to induce ryegrass staggers and decrease productivity of the pasture. For additional information on endophyte toxicity in plants, see *Endophyte Toxins in Grass and Other Feed Sources* EM 9156 and contact your veterinarian or the local county Extension office.

Conclusion

There are a surprising number of plants potentially toxic to livestock. The danger causes ranchers apprehension when turning out livestock and horses to graze pastures. However, grazing pastures is the most economical method for raising livestock. Therefore, the benefits of grazing livestock on pastures far outweighs the danger. Fortunately, management practices exist for preventing poisoning of livestock. The most important practice is consistently providing quality forage in adequate amounts to animals at all times. Do not let pastures become overgrazed and delay moving to another pasture. If timely rotation of livestock to productive pastures is delayed, provide supplemental feed. Ingestion of toxic plants often occurs when pastureland is overgrazed and hungry livestock graze plants they usually avoid. Additional animal production practices that will greatly reduce livestock illness and death from toxic plants include:

- Regularly observe pasture and rangeland for poisonous plants.
- Do not overgraze plants below 3-4 inches (7.5 – 10 cm).
- Introduce livestock slowly to fast growing, lush pastures.
- Test forage and hay for mineral deficiencies, nitrates, and endophytes.
- Exercise caution when grazing plants that are stressed due to frost, drought, or adverse weather conditions.
- Feed livestock and horses prior to turning out on lush pastures to prevent rapid and excessive consumption of forages.
- Grow productive pastures keeping weeds to a minimum.
- Consistently test hay and pastures with a certified laboratory.

Growing and grazing pasture and rangeland for maximum production is vital for the financial health of ranches. Preventing unnecessary illness and death is paramount for ranch stability. Observant graziers providing quality forage to their animals have relatively few issues when grazing pastures. If questions arise, consult your local county Extension office or veterinarian for assistance.

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Appendix Chapter 9

Weighing Various Grazing Philosophies

I.R. McGregor¹

Introduction

Grazing management is a tool that can be used to support the wide variety of goals a land manager may have that include; profit, livestock performance, forage production, environmental sustainability, and wildlife habitat. Grazing systems can be generally categorized into three broad groups; continuous, rotation, and rest-rotation. However, grazing systems that support the goals of each individual livestock operation are more complex than these broad categories, as they are built specifically around the available resources, e.g., weather patterns, environmental characteristics, and existing forage species of each individual production scenario. Proper grazing management should also be flexible to be able to suit the ever-changing environment in which grazing takes place. The rest of this chapter will explore the nature of these grazing systems, implications of forage physiology characteristics, and aspects of unique production scenarios to help determine appropriate grazing strategies.

Grazing Regimen Categories

Continuous

Continuous grazing is defined as “a method of grazing livestock on a specific unit of land where animals have unrestricted and uninterrupted access throughout the time when grazing is allowed” (Allen et al., 2011). Some obvious advantages of this system is that it is low cost, as continuous grazing does not require additional fencing, water infrastructure, and requires very little time and labor. However, the major disadvantage is less control over the time, place, and intensity of grazing. This makes it difficult to be able to graze forages at a particular stage of maturity, which is an important management tool for promoting pasture health and animal body condition. Additionally, partially due to less control of grazing, continuous grazing may result in an un-even grazing distribution, where animals continually focus their grazing activity on higher quality forages, and ignore the rest of the pasture that may contain a lesser quality forage (Ganskopp and Bohnert, 2009). An uneven grazing distribution is great for supporting avian wildlife habitat (Ranellucci et al., 2012), but it has been speculated that this behavior of livestock in a continuous grazing regimen may decrease desirable forage species as they

are replaced by undesirable forage species in some cases. Also, this may result in a lot of available forage not being utilized because livestock are not using the entire pasture, thus not taking advantage of the potential AUM's that a pasture is able to provide. Well managed continuous grazing systems have relatively low stocking rates, which results in large surpluses of forage in the spring and a large quantity of low quality forage in the summer.

Rotational

Rotational grazing is a practice that involves moving livestock among paddocks and allowing them to graze in each paddock for a certain amount of time. A paddock can be defined as an enclosure that exists within a pasture. Rotational grazing can be as extensive as rotating a herd of livestock through four 2,000-acre (809 ha) paddocks and moving livestock 3 or 4 times a year, or it can be as intense as splitting a 20 acre (8.1 ha) pasture into 40 different paddocks and moving livestock almost every day throughout the growing season. Advantages of rotational grazing is a more even grazing distribution where animals are forced to use a larger portion of the pasture, rather than focusing grazing activity on desirable forages. Rotational grazing may allow livestock producers to increase their stocking rates, and subsequently increase their gross income. When rotational grazing is applied to pastures with favorable conditions, this can increase tillering and overall forage production. Some disadvantages of rotational grazing are increased time, labor, and costs associated with things like fence, water infrastructure, handling more animals, etc. Success with rotational grazing is only found with plentiful thought, consideration, research, and pasture monitoring. Rotational grazing can easily be mismanaged, resulting in overgrazing and a sharp decrease in animal productivity. Increasing stocking rates under rotational grazing regimens to a point that results in a decrease in individual animal productivity and warrants the need for additional supplementation has proven to be very unprofitable and detrimental to pasture condition and soil health (Holecheck, 1992).

Rest Rotation

Rest-rotational grazing is where 1 or more pastures are rested for the entire grazing season, while livestock are rotated through the remaining pastures. Rest-rotation generally has similar advantages and disadvantages as rotational grazing. Some unique advantages to rest rotation is that the rested pastures get the opportunity to recover from the previous years' grazing activity, and

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theoretically, this would improve the health and condition of that pasture. Furthermore, by resting a pasture during the grazing season, this creates stores of stockpiled forage for emergency situations, particularly a drought situation where livestock might have run out of available forage in the other pastures too early in the grazing season.

Giving a year-long rest is likely to be very beneficial for the root system of forages. A study conducted by Crider (1955) demonstrated that grazing 50 % of above ground foliage resulted in a complete halt of root growth for several days, and the length of time for the pause of root growth is proportional to the amount of foliage removed. A pause in root growth did not occur when only 40% or less of above ground foliage was removed. While, theoretically, there may not be a difference in root growth between a completely rested pasture, and a pasture where only 40 % of less of above ground foliage was removed at a time, this still provides the pasture a break from other effects of having animals in a pasture such as soil compaction and erosion. However, effects of grazing management from previous years will play a role in the outcome of resting a pasture for a year. If the pasture has been overgrazed in previous years and forages have not been allowed to develop a healthy root system, this would give the competitive advantage to invasive undesirable plants. Resting a pasture for a year may not always be the best decision in terms of pasture health.

Managers with goals in the realm of wildlife presence and preservation should be attracted to rest-rotation grazing regimens. While grazing can help create an uneven grass structures throughout a pasture which has been found beneficial for songbird and sage-grouse brood habitat (Ranellucci et al., 2012; Payne et al., 2017), leaving a pasture completely vacant may provide a peaceful sanctuary for deer and elk that are wary of human activity (Yeo et al., 1993). It has also been observed that herbivorous wildlife like deer and elk enjoy that palatable regrowth that is present shortly after a grazing or fire event.

Considerations

A common theme one might find in exploring grazing strategies is that there is no one-size-fits-all grazing strategy that is appropriate for every landscape and production scenario. In other words, “there is no silver bullet”. There seems to be a lot of misinformation around the United States in regards to grazing, with certain people expressing an allegiance to one grazing system over another. A lot of producers have found great profit and pasture/range improvement by adopting more intensive grazing management. Others may observe greater pasture/range improvement with a higher level of grazing management, but still end up losing a lot of money after investing in the necessary time, labor, and materials.

Additionally, others have adopted a more intense level of grazing management without experiencing pasture/range improvement or increased profitability. Briske et al., (2008) provides a synthesis of many of the experiments that compare continuous and rotational grazing, and substantiated the statement that different production scenarios benefit from different grazing strategies, and that there is no one-size-fits-all grazing strategy. A beneficial grazing strategy is a product of a careful consideration of existing forage species and their unique physiological characteristics, availability of certain resources and the feasibility of utilizing these resources, as well as a persistent pasture monitoring program and the ability to change grazing regimens according to changes in the pasture.

Forage considerations

While attempting to determine the appropriate grazing strategy for a unique scenario, it is of utmost importance to understand the livestock and forages you are managing, and how they will react to different grazing regimens in order to graze in the most efficient way possible. Grazing efficiency could mean a lot of different things to different people, but there seems to be two major concerns when it comes to grazing efficiency; livestock performance and forage production.

Grazing Efficiency: Livestock Performance

The primary concern regarding grazing efficiency in terms of livestock performance is understanding forage characteristics that affect the nutritional quality of the forage. The characteristic of forage that has the most profound effect on its nutritional quality is stage of maturity. Unlike mammals, forage plants do not have an internal skeleton that serves to hold them up as they grow taller. Instead, forages develop an increasing amount of structural fiber in the individual plant cell walls to help them stand taller. This structural fiber is rather indigestible to ruminant livestock and contains minimal nutritional value. As more structural fiber is incorporated into plant cell walls as the plant gets taller, this makes the plant more bulky, decreases concentrations of more desirable nutrients (energy, protein, vitamins, and minerals), makes desirable nutrients more difficult to access by rumen bacteria, and makes the plant less palatable to livestock. Additionally, as forage plants become taller and progress in maturity, diminishing nutritional quality significantly accelerates when the plant reaches a reproductive stage of maturity as much of the plants stored energy is allocated towards creating the seed head.

The grazing management implications of this, concerning livestock performance, is that shorter grass is generally of higher nutritional quality than taller grass. This explains why wildlife are rather fond of grazing

pastures that were recently grazed by domestic livestock (Ranellucci et al., 2012). This demonstrates why it is wise to sort livestock into groups based on their nutritional demands that are influenced by their physiological state. For example, it would be ideal to briefly graze steers and/or dry and open cows on a relatively mature pasture, and then graze the same pasture with livestock with higher nutritional quality demands such as pregnant or lactating cows. This strategy allows the animals with relatively low nutritional demands to make use of the forages of lesser nutritional quality, and get them out of the way so that animals with higher nutritional demands have access to higher quality forage.

Additionally, the leaves of forages are of higher nutritional quality than stems. Perhaps this is an important consideration when selecting a species to plant in a pasture, as different forages have different stem to leaf ratios. For example, perennial ryegrass (*Lolium perenne*) typically will only grow 3 leaves per stem, whereas timothy (*Phleum pratense*) may produce as much as 18 leaves per stem.

Grazing Efficiency: Forage production

Many characteristics of forages with implications in livestock performance also have implications in forage production and pasture health. Shorter forages are generally of higher nutritional quality than taller forages. Energy storage is generally concentrated in the first 3 to 4 inches (7.5 to 10 cm) of above ground growth, as well as the crown. Grazing or cutting forages short enough to remove a significant amount of energy stores will really will damage the plants ability to regrow and will lead to stand loss if this is done repeatedly. There is some variation in the amount of stubble in which energy is stored across forage species, thus translating into grazing recommendations to maintain different stubble heights for different forages. For example, it is recommended to leave at least 3 inches (7.5 cm) of stubble of perennial ryegrass and 4 inches (10 cm) for tall fescue (*Lolium arundinaceum*).

Stem to leaf ratio has implications in livestock performance, as leaves are generally of higher nutritional quality than stems. The nutritious leaves are also where photosynthetic activity, necessary for providing the plant with energy, takes place. Removing a significant amount of this foliage will inhibit the resiliency of a plant. This relates to a previously mentioned study (Crider, 1955) where it was demonstrated that grazing more than 40 % of the above ground foliage of a forage plant is capable of halting root growth for a certain period of time, and this length of time is proportional to the amount of foliage removed.

Root development is vital for forage plant survival and resiliency as the roots anchor the plant in the soil and also serves as the route of absorption for nutrients and

water. Not only are roots vital for plant health, but they contribute a great deal to soil organic matter. Soil organic matter is the primary indicator of soil health, as it serves as a pool for soil nutrients, increases water infiltration into the soil, and decreases soil compaction and erosion. In terms of forage production, health, and long-term sustainability, an understanding of roots and how they react to different grazing treatments is perhaps just as, if not more important than understanding what is going on above ground.

New growing points are formed at the crown of the plant in the fall, and a new root is formed for every immature growing point that is formed. Energy is provided by the previous year's tillers to form the new root and growing point, allow them to survive winter dormancy and resume growth in the spring. Grazing the tillers from the previous growing season close enough to rob it of its energy stores will impede growing point and root generation in the fall and will have a direct detrimental effect on forage production the following spring.

When favorable moisture levels, soil temperatures, and day lengths are achieved in the spring, forages begin growth from the growing points that were developed in the fall, and their corresponding roots continue to grow. Root growth will halt under two circumstances; 1) if the meristem (point of growth) for its corresponding shoot is grazed or cut off, 2) when a seed head emerges from its corresponding shoot. With this considered, the root will have reached its full potential right before the seed head emerges. However, wherever the roots are in their development, they will senesce and shed from the plant when environmental conditions induce summer dormancy. Once they are shed, they will become part of the soils organic matter content. The more root mass that is produced, the larger the contribution to soil organic matter.

Grazing efficiency in terms of forage production and health becomes even more complicated when discreet nuances between species that have significant implications in how they react to grazing is considered. For example, Bluebunch Wheatgrass (*Pseudoroegneria spicata*) is considered a very important forage species for wildlife and livestock on rangeland and is an indicator of rangeland health. Bluebunch wheatgrass is extremely sensitive to defoliation during its growing phase and develops some tolerance to grazing later in the season, after it is done growing. Tall fescue is quite resilient to defoliation throughout the growing season, assuming that it is being grazed according to commonly accepted guidelines. Furthermore, grazing can increase tillering of some undesirable species if grazed at the wrong time. Knowing what forage species are being grazed, and thorough knowledge of their physiological characteristics is extremely important in effectively managing pastures.

Grazing Efficiency: Finding the Balance

Grazing strategies that promote livestock performance or forage production and health conflict with one another. While shorter forages and leaves are of high nutritional quality, it tends to work against forage health to graze them too short, or to remove too many leaves. While this may vary across forage species, it is generally accepted that grazing forages at their boot stage of maturity provides the best balance between forage nutritional quality, quantity of feed produced in a pasture, as well as forage and soil health. The boot stage is the stage of maturity that is right before a seed head emerges from the plant, and the seed head is actually found within the sheath of the uppermost leaf collar (aka flag leaf). This stage supports nutritional quality as this stage occurs before the steep decline in nutritional quality associated with the appearance of a seed head. This also optimizes the tonnage of forage produced in a pasture, without making an unreasonable sacrifice in nutritional quality. Grazing at the boot stage also allows time for growing roots to get close to their full potential. This enhances the plant's ability to absorb nutrients and water from the soil, and greatly contributes to soil organic matter. **This recommendation is mostly relevant to tame irrigated forages. Many wild, rangeland grasses do better when they are grazed at a later stage of maturity, after carrying out its reproductive cycle.**

Resources and environmental

Increased forage production with a well thought out grazing regimen with forage physiology in mind certainly seems very achievable. However, implementing such a grazing regimen may require significant financial investment in fencing, water sources, time, and labor. Additionally, if things go wrong, you might find yourself having to spend money to supplement livestock. The big question is, how confident are you that the increased forage production because of your grazing management decisions is going to overcome the associated costs? Operations that have access to resources like irrigation and fertilizer and operate in pastures that are small and accessible enough to utilize these resources, are far more likely to find success with intense grazing management.

Water is a necessary ingredient for photosynthesis to create the energy needed for a forage plant to recover from a grazing event. Making sure the water needs of forages are met after a grazing event promotes prompt growth and recovery. In areas of high elevation, low humidity, and infrequent precipitation, forages will generally have a much harder time recovering, thus increasing the risk of overgrazing. Many of the studies since the 1970's that have observed spectacular range or pasture improvement were scenarios where there was either a high level of precipitation or access to irrigation. If your grazing operation takes place in a scenario

with minimal or unpredictable access to water, it may not be possible to increase forage production enough through grazing management to overcome the costs associated with implementing higher intensity of grazing management.

Irrigation water still costs money, especially when also considering the cost associated with the energy to pump that irrigation water. You might find that sometimes you observe significant growth in a pasture after an irrigation set, and other times you might not observe a response at all. Needlessly irrigating a pasture where the water is not being used by the plants would be considered a complete waste of that resource and will not help forages recover from a grazing event. Watering too much can also impede respiration of the plant through the roots, which will do worse for the plant than good. Irresponsible irrigation will only increase your costs, thus lowering your net profit. Having access to irrigation will only improve forage production and health if irrigation methods are well thought out. It would be wise to refer to the publicly available Agrimet system to better understand the exact water requirements of your pasture, as Agrimet evapotranspiration data is based on information from weather stations that determine water use by different crops based on ambient temperature and humidity (<https://www.usbr.gov/pn/agrimet/>). Furthermore, consideration towards soil type should determine the frequency and length of irrigation sets. For example, clay type soils may require relatively more frequent, shorter irrigation sets, as water infiltration into this type of soil is low and applying too much water will result in excessive runoff. On the other hand, sandier soils may benefit from longer, and less frequent irrigation sets, as water infiltration into these types of soils is rather high. Assuming water infiltration into the soil is adequate, it has also been demonstrated that longer and less frequent irrigation sets encourage forage roots to reach greater depths into the soil.

Forage plants might not respond to irrigation if soil fertility needs are not met. Therefore, careful thought towards soil fertility management is also important when implementing an intense grazing regimen or enhancing forage production and health when attempting an increased stocking rate in a continuous grazing regimen. Fertilizer also costs money, so your net profit will suffer if fertilizer is being applied in an ineffective or damaging manner. It has been demonstrated that applying fertilizer after a wet year is more effective than applying fertilizer after a dry year (Bohnert et al., 2011). It has been speculated that the increased growth the previous year because of higher precipitation accelerates soil nutrient depletion. Therefore, the demand for nutrients the following season is greater, and fertilizer will have a more significant impact. Applying fertilizer in excess can cause forages to grow very quickly. If forages grow too quickly, this can significantly decrease energy concentration in

the plant. This is especially important in the fall, where this decrease in energy concentration will make it difficult for the plant to survive after winter dormancy. Applying excess nitrogen can also lead to high nitrates in the forage, which will cause deleterious health affects in livestock, and in some cases, death. It is important to conduct a soil analysis on an annual basis, preferably in the fall after previous crops have influenced soil nutrient concentrations. This way you can be sure that you can apply fertilizer when the plants need it and avoid fertilizing in an ineffective or damaging manner.

Smaller, more accessible pastures make it feasible to use irrigation and fertilizer. Operating on large pastures, with significant topographical features will make using these types of tools too expensive, too difficult, or perhaps impossible to use. The lack of ability to use these resources, along with the huge amount of fence and water sources needed to implement rotational grazing in large, rather unproductive pastures makes finding success with any kind of intense grazing regimen very unlikely.

Rotational Grazing Alternatives

Rotational grazing is a fantastic tool that allows a manager to have complete control over the time, place, and intensity of grazing. This can be used to a managers advantage so that grazing can take place at a time that provides the best balance between forage quality, quantity, and health. However, rotational grazing may not be the responsible choice in scenarios with limited resources, and/or large, unproductive pastures with rough terrain. While managers have less control over grazing behavior when implementing continuous grazing, managers can still create profits while making careful management decisions that favor forage and soil health.

Having a flexible stocking rate is one of the most important management tools a pasture manager can have when dealing with weather conditions and subsequent forage production that varies from year to year. Torell et al., (2000) recommends that only 50 % of any given herd to consist of brood cows, with the remainder of the herd consisting of backgrounding steers and heifers. Brood cows are typically long-term investments, as the break-even point (financially speaking) comes after a handful of years producing calves. Backgrounding steers and heifers are much more liquid, as they can be bought or sold at the local auction yard on a weekly basis, and profit is made on the weight they gain from grazing on a daily basis and are not necessarily a long-term investment. This type of management allows managers to adjust annual stocking rates according to forecasted forage production because of precipitation forecasts and winter snowpack so that the pasture-based livestock business can survive years of drought, while being able to take advantage of good water years.

After appropriate stocking rates are determined, pasture managers still have some other tools at their disposal to influence grazing behavior. A major disadvantage to continuous grazing is that the animals may not use the entire pasture, thus allowing many AUM's not to be utilized properly. It has been well established that the strategic use of supplements can be used to alter grazing behavior. Bailey and Welling (1999) used pastures that were categorized as easy, moderate, and difficult terrain to observe the effect of molasses supplementation on the grazing distribution of the pastures of various levels of terrain difficulty. By placing the supplement in areas of the pasture that are underused due to terrain difficulty, they were able to convince livestock to go to these areas, and subsequently enhance the grazing intensity in these areas. Freeman et al., (2006) and George et al., (2008) observed that by strategically placing molasses/protein supplement in the upland areas of rangeland pastures, this decreased grazing intensity of riparian areas located in the lowland areas. This strategic placement of supplement also increased the amount of AUM's being used by the livestock, thus allowing livestock to remain on these allotments for as much as an additional 2 weeks with minimal damage to riparian areas. This research goes to show that providing strategically placed supplement in pastures can be used as a tool increase utilization in underutilized areas and potentially increase the AUM's available for livestock. Water is another feature that livestock are attracted to, and pasture use in areas adjacent to water sources is usually high. Water consumption will increase the appetite for salt by livestock. For this reason, placing salt blocks right next to water sources is commonly discouraged. However, strategic placement of salt blocks a reasonable distance from a water source is another way to encourage livestock to graze in certain areas.

While there are ways that exist to influence grazing behavior and get more AUM's from a pasture in continuous grazing systems, this will never live up to the caliber of efficiency and control managers have when they manage pastures in scenarios where it is reasonable to invest in the equipment and labor necessary to implement a more intense grazing regimen. Managers using intense grazing regimens are better able to profit on forage production and subsequent pounds of beef produced, which managers using continuous grazing regimens might achieving. Holecheck (1992) compared management practices with high monetary input with management practices of low monetary input in terms of their financial outcomes in the Chihuahuan Desert of New Mexico. Management strategies with high monetary input maintained a focus in brush control, grazing management, and beef production, while low monetary input systems focused on conservative stocking rates, reproductive performance of livestock, and replacement

heifer management. The management strategy that was demonstrated to be most successful in the landscape of the Chihuahuan Desert was the low monetary input strategy that utilized a continuous grazing regimen, with a focus on conservative stocking rates, superior conception and calving rates, and a carefully thought-out heifer replacement program. Of course, a higher level of monetary input to support a well-managed rotational grazing program would prove to be superior in places of high precipitation and forage production, such as the Willamette Valley of western Oregon. Intense rotational grazing in the Inland Pacific Northwest may not be ideal on expansive rangelands. With a high degree of uncertainty in regards to annual irrigation water supply for irrigated pastures in the Inland Pacific Northwest, stockers could be purchased, and rotational grazing could be practiced during good water years, while keeping conservative stocking rates and grazing pressure during bad water years. However, when it is determined that continuous

grazing is more appropriate for a certain pasture, focus should be emphasized on the reproductive performance of the herd.

Concluding Thoughts

Alterations in grazing management can create either very positive or very negative results. When thinking of implementing a change in grazing management, particularly changes that involve frequent rotations, it is wise to experiment with new strategies on a rather small scale. This way, if something goes wrong, it happens on a smaller, more manageable scale. Pasture managers should always be monitoring their pasture for changes in desirable forage species, undesirable species, as well as bare spots and erosion. The most important tool a pasture manager has is the ability to be flexible, as adjustments in stocking rate is the most effective way to ameliorate the negative effects of poor grazing management decisions.

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Appendix Chapter 10

How Grazers Change the Pasture Environment

Glenn Shewmaker and Scott Jensen¹

There is a truism for pasture and grazing management, “You get what you manage for.” If you overstock or more likely allow continuous grazing, you will shift plant composition and form to grazing-resistant individual plants and species. Understocking or grazing with low stock density can create patch grazing patterns with some plants grazed too close and often, and some areas and plants that are not grazed. Sowing a pasture with the “best variety of grass” doesn’t ensure long-term success. Although using good genetic resources is recommended, they will be overcome by poor grazing management in a few years. A pasture that resembles a golf green before seeding with a best new variety will still look like a golf green later if management does not change.

The converse can also happen. When good grazing management was applied on a previously continuously grazed pasture, we observed an obvious shift in plant composition from Kentucky bluegrass (*Poa pratensis*) to orchardgrass (*Dactylis glomerata*), meadow bromegrass (*Bromus biebersteinii*), tall fescue (*Lolium arundinaceum*), and several legumes over three years. These more desirable species and plants existed in the pasture composition but were unable to be productive, with significantly reduced vigor. When plants were allowed to recover photosynthetic capacity from rest and buildup of carbohydrate reserves in the stubble and crown, plant vigor improved.

Grazers and Stubble height

Different species require different stubble heights or residual—remaining vegetation after grazing—to 1) maintain photosynthetic capacity, 2) allow the growing point, apical meristem, to continue tiller extension, and 3) extend root growth. For example, perennial ryegrass will maintain only three leaves and is resistant to grazing, so the recommendation is to begin grazing at the 3-leaf stage on the majority of tillers. In contrast, smooth bromegrass will maintain many leaves and the recommendation is for longer rest between grazing events. On timothy (*Phleum pratense*) at heading, 18 leaves have been counted per tiller prior to hay harvesting. Orchardgrass is intermediate, but the leaves of this bunch grass stand erect and require a 4 to 5-inch (10 to 12.5 cm) stubble height to capture enough photosynthetically active light (Figure 1) to remain vigorous.

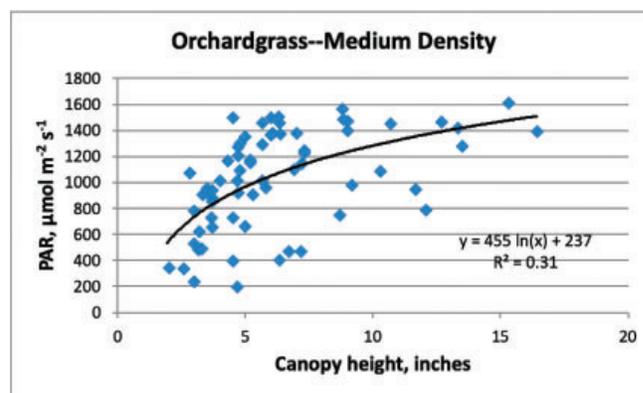


Figure 1. Photosynthetically active radiation (PAR) intercepted by *Dactylis glomerata* canopies as a function of canopy (sward) height in medium canopy densities across 2 growing seasons and 2 sites in south-central Idaho (Shewmaker and Hooper, 2013).

Good grazing management positively impacts plant vigor. Vigorous plants will have deeper and more abundant roots. This results in more efficient water and nutrient uptake, and more effective photosynthesis. Better grazing management results in better pore space and water infiltration, more carbon sequestration, and improvement in other soil properties.

Grazing animals exert pressure on the ground comparable to crop tillage with agricultural machinery. The soil under pasture can be compacted and there is little opportunity to mitigate poor soil physical conditions through tillage. Hence, it is important to understand the effects of grazing on physical soil properties and how this affects pasture growth and composition.

Grazing wet pastures will cause soils to be compacted to some extent, even those managed to minimize soil physical degradation. However, the magnitude of this compaction is usually small, and limited to the upper 2 to 6 inches (5 to 15 cm) of the soil. Compaction to greater depth, and other negative changes in physical soil properties, are more likely in recently tilled, wet soils.

Grazers affect how plants grow, and plant response to defoliation affects how grazers graze. There is variation in chemical composition and thus nutrient concentration within the vertical distribution of forage available to grazers. The proportion of leaf material decreases, and the proportion of stem and dead material increases resulting in reduced nutrient concentration as the animal grazes progressively down through the sward. Grazing modifies plant morphology and chemical composition. Repeated defoliations of the same area will result in a reduction of bite mass, intake rate, and crude protein and sugar content, but an increase in structural carbohydrate

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content of the material ingested. Thus, increased grazing time and decreased bite mass common on short swards as compared with taller swards, as well as increased rumen fill and increased amounts of energy gained from rumen fermentation end products, were found after longer regrowth of pasture (Chilibroste et al., 2000).

Performance of high-producing livestock, such as lactating dairy cows or finishing cattle, can be limited by forage intake. Forage intake is primarily a function of biting rate, grazing time, and dry matter (DM) intake rate:

$$\text{Forage intake} = \text{biting rate (bites/minute)} \times \text{grazing time (minutes/day)} \times \text{intake rate (grams DM/bite)}$$

Cows work hard seven days a week, 365 days a year. Their survival depends on it. They also belong to the cow union, however, and will not graze more than about 12 hours per day! They must also have time to ruminate or “chew their cud,” meaning they regurgitate their food and chew it again.

There is also a limit to how many bites animals can take per minute. High-producing dairy cows may have biting rates of up to 60 bites per minute (40,000 bites per day), while low-producing cows may take only about 25,000 bites per day.

With limited grazing time and bites per minute, animals must maximize the amount of intake per bite. If they do not get enough sustenance in 12 hours, they will lose weight or exhibit decreases in production. Sward height and mass affect bite size and intake rate. A pasture must have at least 2,000 pounds (907 kg) of forage DM available for an animal to realize 100 percent of its intake potential (Figure 2). Thus, managing pastures to maintain proper sward height and density can influence grazing behavior for optimal intake.

Your goal for grazing animals is to optimize intake. Several animal and pasture factors influence intake rates. As a manager, you can manipulate these factors to improve intake. Keep the following factors for bite size and sward characteristics in mind (Crane et al., 2010):

Bite size:

- Bite size (ounces of forage dry matter per bite) has a greater influence on intake than does bite rate or grazing time.
- Bite size increases with forage quality and leaf density.
- At a feeding station, cattle graze in horizons from the top of the sward to the soil surface. Higher horizons provide deeper, heavier bites.

Sward characteristics:

- Optimal intake on pastures is often limited by herbage height (low vertical density). As sward height decreases, bite size declines and grazing time must increase. Conversely, intake on rangelands is limited by herbage density (low horizontal density).

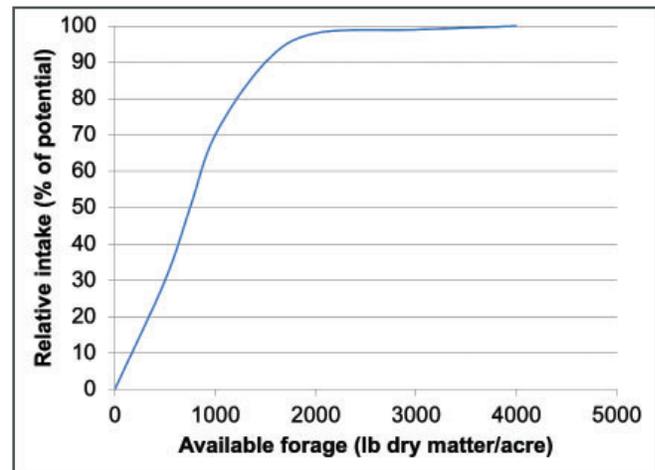


Figure 2. Availability of forage affects animal dry matter intake. (Adapted from Martz, Tate, and Gerrish. 1999. Meeting nutritional needs of livestock from pasture. In Gerrish, J. and C. Roberts, eds. Missouri Grazing Manual. MU Extension, University of Missouri-Columbia)

- On grazed pastures, bite size and intake generally increase with forage abundance and height. However, animal gain has not been shown to necessarily increase with the height of grass. Digestibility often decreases as forage height increases. Additionally, lodging and trampling are more likely to occur and may decrease access to leaves of forage plants.
- The presence and accessibility of leaf material are both important factors in forage quality. For example, switchgrass has a lower proportion of leaves to stems than bermudagrass, but it produces better cattle gains because leaves are more accessible (taller).
- Large herbivores are at a disadvantage when grazing short swards because each bite represents a smaller portion of daily requirements.
- Animal diets are higher in quality than the overall quality of the pasture because animals can select leaves over stems and live portions of plants over dead portions.
- Cattle will select “normal” over lodged swards, but it is possible to maintain intake rates on lodged swards.

Good grazing management will improve livestock productivity as measured by average daily gain or milk production. For example, Abrahamse et al. (2008) confirmed that increased pasture allocation frequency from once every 4 days to once a day improved milk production in grazing dairy cows, especially when the amount of pasture availability was high. This was mainly the result of a change in grazing behavior, resulting in an increase in pasture dry matter intake. Concentrations of crude protein and sugars decline with each day in the same pasture as livestock selectively graze the most

desirable plants first, while concentrations of neutral detergent fiber and lignin increased each day of continuous pasture grazing.

Summary

Good grazing management affects plant species abundance, plant vigor and growth characteristics of pasture plants. Good grazing management maintains plant vigor, which results in deeper and more abundant roots. This results in more efficient water and nutrient uptake, and more effective photosynthesis. Better grazing management results in better soil pore spaces and water infiltration, more carbon sequestration, and improvement in other soil properties. These practices influence how grazers affect the environment.

Intensive management and rotational grazing systems can optimize production per livestock unit and per acre. Intensive grazing management allows for abundant

forage or pasture height which affects bite size, the major factor controlling pasture intake. If a grazing manager allows livestock to regraze a pasture or overconsume the forage by continuous stocking, as pasture height decreases:

- A. Bite size decreases.
- B. Biting rate increases.
- C. Grazing time must increase.

Although forage dry matter intake can be maintained temporarily by the grazer adjusting with the above rates in B and C, there are physical limits to these relationships and soon animal production becomes limited. Grazing animals don't plan for the next days feed, they just eat the best feed available until it is gone. Grazing managers should plan for the grazers and allocate forage to them for optimal livestock production.

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Appendix Chapter 11

Sustainable Pasture Management

K. Christy Tanner and Joseph Sagers¹

Sustainable production practices are those that meet the needs of today without compromising the needs of tomorrow. This can vary widely with each operation, but the basic principles are the same. An operation with a single horse and two acres (0.008 km²) is going to manage their plant growth and soil nutrients differently than a 1,000-cow grazing dairy. But the basic principles are the same: both must avoid overgrazing, over-harvesting or spending too much or too little, in order to be sustainable.

There are three aspects of sustainability that should be considered: environmental, economic, and social. Environmental sustainability requires that practices do not cause damage to the environment or natural resources. This would decrease the environment's ability to provide beneficial ecosystem services such as forage production and clean water. Farms, ranches, and other operations do not last long if they are not economically sustainable. Cutting costs now might seem like a good financial decision, but this can create expensive problems for the future. In terms of social sustainability, the farm or ranch should support the health and wellbeing of the people who own, manage, and work there.

Sustainability can be applied on multiple levels. For most producers it makes the most sense to focus on sustainability at the field and farm scale and being able to pass the farm or ranch on to their children or grandchildren. At this scale, practices that are environmentally sustainable are often economically sustainable because agricultural systems rely on natural resources. Production practices that degrade soil health or pasture productivity will result in decreased future productivity, and this degradation is costly to correct.

Field scale sustainability

To maintain high pasture productivity, pasture plants must be kept healthy. Perennial forage species have stored reserves of energy and nutrients that they use to re-grow quickly after cutting, grazing or dormancy. These reserves are rebuilt once leaf area increases enough the plant can produce more sugars than it is using for growth. Plants need an opportunity to rebuild sugar reserves for pastures to remain healthy and productive. If forage species are managed in a way that depletes plants' energy reserves, the plant will not be able to re-grow quickly. Cutting or

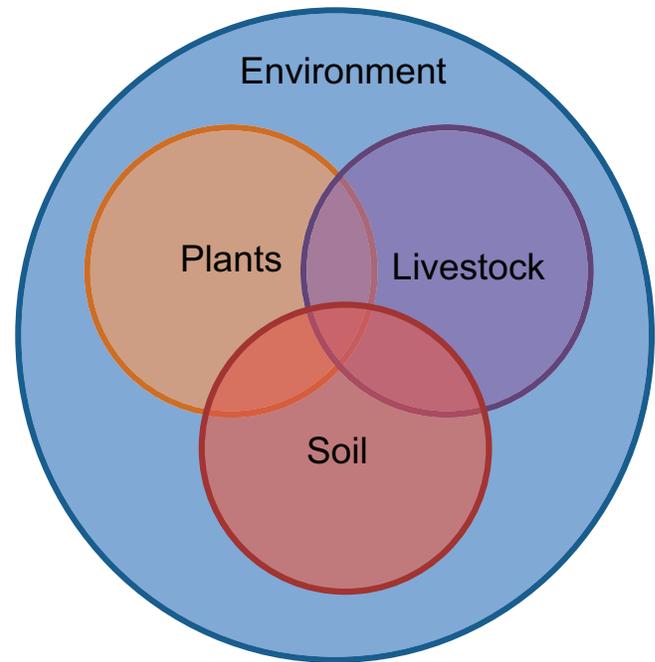


Figure 1. Sustainable pasture management needs healthy plants, soil and livestock, within a healthy environment.

grazing too often can prevent the plant from rebuilding its energy reserves. Since the energy reserves are stored in the base of the stems, cutting or grazing too low can remove the energy reserves before the plant can re-grow. Overgrazing and poor harvest management are not sustainable because they deplete plant's energy reserves and cause a decline in pasture productivity over time.

As the health of pastures declines over time, desirable species are replaced with weeds and species that are resistant to overgrazing. These species are typically less productive and lower quality than desirable forage species. The only way to increase pasture productivity once this occurs is to re-plant the pasture. Re-planting pastures is one of the largest pasture management expenses, so management that increases how often pastures must be replanted, negatively affects the economic sustainability of the operation. Management that maintains plant health in pastures results in higher productivity, lower herbicide input costs and less frequent re-establishment costs.

Plants mine nutrients from the soil and use them to build plant structures such as roots, shoots, leaves, and seeds. Under a natural grazing system, those nutrients are consumed by grazing animals and used for growth and maintenance, then the majority of the nutrients are returned to the pasture system through the

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decomposition of manure and urine over time. If hay is harvested and fed in another field or sold off-farm, the nutrients in the hay are exported from the field. One ton of harvested alfalfa hay contains approximately 56 lb (25.4 kg) of N, 8 lb (3.6 kg) of P_2O_5 , 54 lb (24.5 kg) of K_2O , 5 lb (2.2 kg) S, 30 lb (13.6 kg) Ca and 6 lb (2.7 kg) Mg (Koenig et al., 2009). If hay is harvested repeatedly without replacing the nutrients that are lost, the productivity of the field will decline over time. Pasture soil fertility and productivity long term will be maintained by monitoring nutrient levels with soil tests and replacing exported nutrients through fertilization. When deciding whether to graze or hay a field, the cost of replacing nutrients that are removed in hay should be considered.

Water soluble nutrients can be lost through runoff or leaching. Many elemental compounds essential for plant growth are somewhat mobile in the soil because of their ability to dissolve in water. This makes them convenient for the plants to absorb the nutrients through the roots and utilize in building new growth. Nutrients are diluted once they go into solution after irrigation or rainfall. If the soil exceeds its maximum water holding capacity, then the excess water must go somewhere, and it leaves the system as runoff or leaching, taking dissolved nutrients with it. In a sustainable system runoff and leaching must be mitigated, or the lost nutrients must be accounted for. Runoff can also lead to erosion or the loss of soil from fields. This is rarely a problem in healthy pastures, but can be an issue in bare, over grazed areas and new plantings. Unlike nutrients, soil should be considered irreplaceable.

Soil organic matter is an important consideration for sustainable soil management. Soil organic matter acts as a sponge that soaks up water and nutrients and releases them to plants when needed. Soil texture and climate are the main things that control the amount of organic matter present in a soil, but management can have an important effect. Keeping the soil covered with a living perennial crop and minimizing tillage helps maintain and increase organic matter. Increased soil organic matter increases the efficiency of irrigation and fertilizers. See appendix chapter 4 for more information.

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Sustainability at larger scales

Compared to other agricultural production systems, pasture-based livestock systems have many advantages in terms of sustainability (Gwin, 2009). The input requirements for pastures are low because grazing animals efficiently recycle nutrients. Perennial forage systems promote soil health because tillage is rare, the soil is covered year-round and protected from erosion, and root growth and manure inputs increase soil organic matter. Increased soil organic matter is evidence of carbon sequestration and results in improved soil water storage and nutrient cycling. While the feed used by livestock often contains more calories and nutrients than the resulting meat or milk products, livestock can utilize forage that humans cannot eat. Pasture based livestock systems are a way to produce food from marginal or steep land that is poorly suited for the production of human edible crops.

Consumers want products that are produced sustainably, and many producers want to improve the sustainability of their operations both to meet consumer demands and for their personal values. The first step to improving the sustainability of a farm or ranch is optimizing management and utilizing best practices. Careful nutrient management, irrigation management and grazing management results in efficient use of natural resources and limits negative impacts off farm. Well managed operations have minimal nutrient losses, waste little water, and are economically sustainable because inputs are not wasted. To improve sustainability at larger scales, managers should consider how their operations fit into the larger food production system. Consider ways that the operation might be positively or negatively impacting the sustainability of the system and work to address solvable problems. Impacts might come from the production of inputs (upscale use of non-renewable resources, carbon emissions, pollution), pollution from the farm (at scale erosion, nutrient losses, greenhouse gas emissions) or processing and transport of farm products (multi-scale). Small steps toward sustainability will add up over time.

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Appendix Chapter 12

T-Sum N Fertilizer Timing for Grass Pastures and Hay Fields

Mylen Bohle¹

Explanation of T-Sum 360 F and T-Sum 720 F Nitrogen (N) Timing System

Temperature (T)-Sum 360 F system of applying nitrogen (N) fertilizer for grass forage production is a method for determining the optimum time to fertilize grass pastures in the spring to increase *earlier* forage production. T-Sum 720 F system determines the best timing to apply nitrogen fertilizer to optimize grass hay production on first cutting. T-Sum timing is founded on the concept that spring green up for grass does not likely occur on the same calendar date, but rather on weather conditions of a particular year – based on air temperature. Root regrowth begins slightly earlier. There can be many weeks difference from year to year at the same site, when a certain number of growing-degree-days (GDD's) are accumulated. The theory is when a certain number of growing degrees are reached, then that is the optimum time to fertilize with N.

In the United Kingdom, the Netherlands, Willamette Valley, and Central Oregon, research has shown the optimum time to fertilize grass pastures was around 360 GDD's Fahrenheit (F). In British Columbia, the optimum time to apply N varies between 360 F and 540 F GDD's for pasture, depending upon the location. These PNW areas, west of the Cascade Mountains, receive excellent precipitation in the winter and experience springs like the United Kingdom and the Netherlands, which is different from the area east of the Cascade Mountains. Spring-time frosts are also less severe west of the Cascade Mountains.

Table 1. Example of how to calculate growing degree-days (GDD's F) for a weather station site or using your own thermometer to monitor daily temperature

Date: January,	Degrees F						Accumulated GDD's From January 1
	High	Low	Add high & low Equals	Divide by 2 Equals Average	Minus 32 degrees F	Equals GGD's	
1	47	34	81	40.5	32	8.5	8.5
2	45	29	74	37	32	5	13.5
3	59	33	92	46	32	14	27.5
4	51	34	85	42.5	32	10.5	37.5
5	44	28	72	36	32	4	41.5
6	47	36	83	41.5	32	9.5	51.0
7	51	34	85	42.5	32	10.5	61.5
8	42	30	72	36	32	4	65.5
9	36	16	52	26	32	0	65.5
10	49	23	72	36	32	4	69.5

<http://uspest.org/cgi-bin/ddmodel.us> will calculate online.

The base temperature of 32° F (0°C) is utilized for the T-Sum 360 F and T-Sum 720 F Timing system. Different crops have different base temperatures in which they grow. Cool-season grasses and alfalfa have a base temperature of 41° F (5°C) for growth. Cereals generally have a base temperature of 32° F while warm season grasses, corn, soybean, and grape have a base temperature of 50° F (10°C) for growth.

The T-Sum 360 F and T-Sum 720 F Timing system is calculated by summing maximum and minimum temperature in degrees F, divide by 2, and then subtract the base temperature of 32° F (0°C), starting on January 1st. Positive average numbers are accumulated, until 360 GDD's or 720 GDD's are reached. Any number less than zero, is discarded or treated as zero GDD's. These daily GDD's numbers are then added over time from January 1st. When approximately the optimum number of GDD's is accumulated, it is time to fertilize with N to increase earlier forage production for pasture or to optimize grass hay yield. "Simple Average" method is used to determine T-Sum 360 F and T-Sum 720 F GDD's. Table 1 demonstrates an example of how to sum GDD's.

T-Sum 360 F N Timing System

The largest expense for a livestock enterprise is winter feed costs. If an operation can stockpile forage from late summer, to-be-utilized in the fall and early winter for

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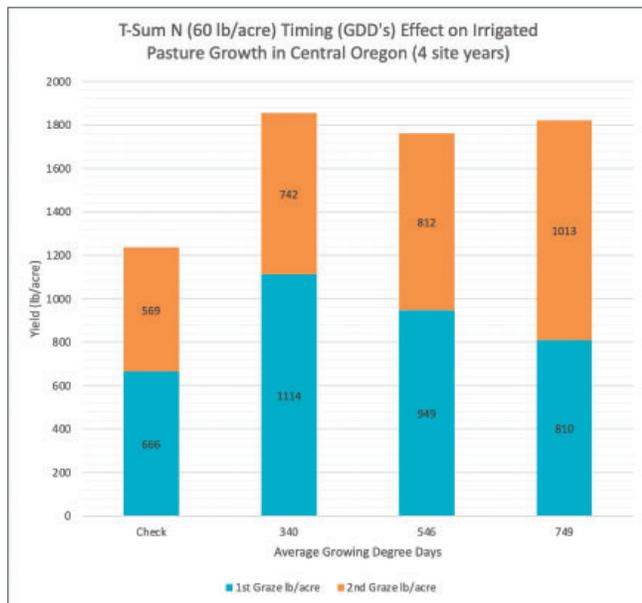


Figure 1. T-Sum N Timing (average GDD's) effect on first and second grazing forage yield in Central Oregon (4-site years). The average time between 1st and 2nd grazing was 24 days with a range of 20 to 30 days. Sixty (60) lb / acre (67 kg / ha) N (ammonium nitrate source) was applied at the different growing degree timings. Mylen Bohle and John Hart, Oregon State University. Unpublished data.

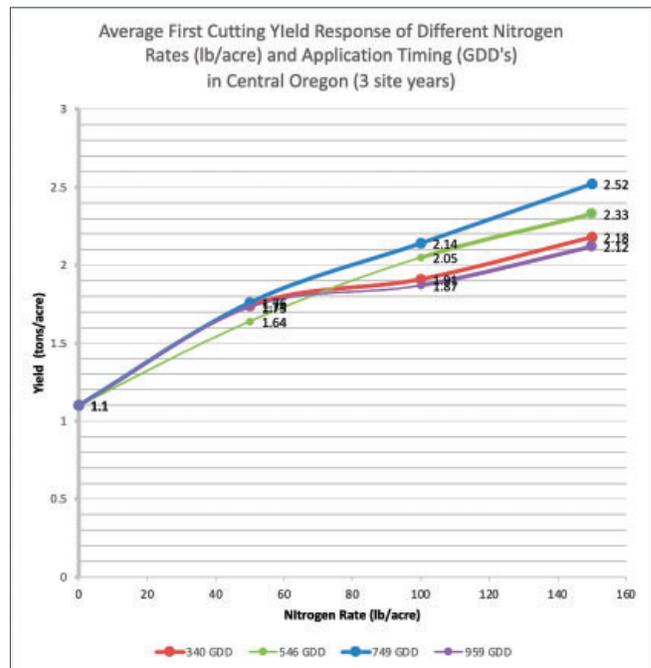


Figure 2. Means are from three 3-site years (1999 & 2000). GDD in F. Yields presented on a 10% moisture basis. Harvest dates were June 1, 6, & 17 for the three sites. Mylen Bohle and John Hart. Oregon State University Unpublished data

Table 2. Irrigated pasture protein content (%) response to nitrogen fertilizer timing based on GDD's accumulated from January 1, in Central Oregon.

Nitrogen rate applied at average GDD's F from January 1	First Grazing Crude Protein (%)	Second Grazing Crude Protein (%)	Average Crude Protein (%)
Check (0 lb / ac N)	16.4	15.2	15.8
340 (60 lb / ac N)	17.6	15.9	16.7
546 (60 lb / ac N)	19.2	15.9	17.5
749 (60 lb / ac N)	20.3	16.0	18.1

Average of 4-site years (1999 and 2000). The average time between 1st and 2nd grazing was 24 days with a range of 20 to 30 days. Mylen Bohle and John Hart, Oregon State University. Unpublished data.

grazing, then that can reduce conserved feed costs. To reduce conserved feed cost coming out of winter, one can utilize the T-Sum 360 F Nitrogen (N) fertilizer timing practice to create earlier pasture forage production by moving up the N fertilizer application date if earlier pasture growth is desired.

Earlier and higher forage production for grazing can-be-achieved by applying N fertilizer based on thermal time (GDD's), rather than on calendar time. Applying N fertilizer at around 360 GDD's stimulated earlier pasture growth and increased yields, on average of

about 5 - 6 animal unit days (AUD) per acre (30 lb / ac UD) (34 kg / ha UD) (Figure 1.). Applying N at the optimum time with some precipitation increased earlier forage production. Table 2 shows the crude protein (%) response of N fertilizer timing application based on GDD's from January 1. The total amount of forage produced through two grazing periods, is approximately the same, but timing of nitrogen application will impact when the forage can be utilized.

Of course, there are constraints such as the fertilization date based on GDD's could be too far ahead of when irrigation water is available. Therefore, properly coated urea must-be-used and applied to reduce volatilization of urea for up to for 30 days (Appendix Chapter 3). Properly coated urea products need a half inch of precipitation to leach the fertilizer into the soil and to keep the N from volatilizing. Applying earlier, one hopes the weather reports are accurate, in order to be able to apply N fertilizer in advance of a rain or snowstorm. The variability shown for GDD's and optimal application timing shown in Table 3 is also going to be greatly influenced by when adequate moisture was forecast to reduce N volatilization, once applied.

Table 3. Examples of earliest, latest, and average growing degree day (GDD) dates occurred for different Oregon elevation sites at Christmas Valley (4360'), Powell Butte (3199'), Madras (2440'), Ontario (2260'), Parkdale (1260'), and Hermiston (607'), Oregon, to apply N at the optimum time for grass pastures and hay fields. Locations are Agrimet weather station data. <http://uspest.org/OR/index.html>

Dates	180 GDD's	360 GDD's Fertilize Pasture	540 GDD's	720 GDD's Fertilize Hay	900 GDD's
Christmas Valley, 4360 ft. - 13 years (2008-2020)					
Earliest	Feb 5	Mar 11	Mar 25	Apr 16	Apr 30
Latest	Mar 20	Apr 25	May 9	May 18	June 3
Average	Feb 27	Apr 3	Apr 17	May 2	May 17
Range (days)	46	45	45	32	34
Powell Butte, OR, 3199 ft. - 23 years (1998-2020)					
Earliest	Jan 20	Feb 8	Mar 4	Apr 1	Apr 9
Latest	Feb 21	Mar 31	Apr 21	May 3	May 15
Average	Feb 8	Feb 25	Mar 23	Apr 16	Apr 21
Range (days)	32 days	52 days	48 days	33 days	26 days
Madras, OR - 2440 ft. - 25 years (1996-2020)					
Earliest	Jan 21	Feb 10	Mar 5	Mar 17	Apr 4
Latest	Mar 17	Mar 23	Apr 26	Apr 25	May 6
Average	Feb 23	Mar 3	Apr 5	Apr 6	Apr 20
Range (days)	61 days	42 days	52 days	39 days	32 days
Ontario, OR – 2260 ft. - 13 years (2008-2020)					
Earliest	Feb 5	Feb 27	Mar 15	Mar 23	Apr 2
Latest	Mar 12	Mar 25	Apr 13	Apr 25	May 4
Average	Feb 28	Mar 12	Mar 30	Apr 9	Apr 18
Range (days)	35	27	29	33	32
Parkdale, OR – 1480 ft. - 13 years (2008-2020)					
Earliest	Jan 24	Feb 15	Mar 7	Mar 17	Apr 8
Latest	Mar 12	Mar 31	Apr 11	Apr 25	May 7
Average	Feb 17	Mar 9	Mar 25	Apr 6	Apr 23
Range (days)	52	45	35	39	29
Hermiston, OR at 607 ft. - 13 years (2008-2020)					
Earliest	Jan 23	Feb 6	Feb 26	Mar 9	Mar 22
Latest	Feb 20	Mar 25	Apr 4	Apr 13	Apr 20
Average	Feb 6	Mar 1	Mar 16	Mar 27	Apr 6
Range (days)	28	47	37	34	29

First Cutting Grass Hay Response to T-Sum 720 N Timing

The best time to apply N fertilizer for first cutting grass hay fields is around 720 GDD's for high rates of N (Figure 2). The timing of applying lighter rates of N to grass hay fields is not as critical, unless applied way too late to utilize the optimal part of the growing season. The T-Sum N Timing yield response was best for around the average 749 GDD's for applying high rates (100 and 150 lb / ac) (112 and 168 kg / ha) of nitrogen fertilizer. For lighter rates of nitrogen, in the 50 lb / ac (56 kg / ha) range, there is not much yield difference between application timings. The leaves on the plants, that had the two highest rates of nitrogen applied early, had a lot more frost damage.

Selected Oregon Site Examples of when T-Sum Occurs

Table 3 shows the earliest, latest, average between earliest and latest dates and range of days for selected GDD's dates of selected T-Sum N Timing dates for Christmas Valley (4360') (1329 m), Powell Butte (3199') (975 m), Madras (2440') (743 m), Ontario (2260') (691 m), Parkdale (1260') (384 m), and Hermiston (607') (204 m), Oregon representing different elevation sites in eastern Oregon. The web site for all the states in the United States is <http://uspest.org/cgi-bin/ddmodel.us>. Use "T-Sum 200 fertilization forage management" program for pasture (200 Centigrade equates to 360 F and use 720 F for grass hay). Specifically for Oregon sites: GDD's can be calculated to track the thermal time or growing degree-days at: <http://uspest.org/OR/index.html>. It also has the T-Sum 200 C program you can use for pasture at this site.

For fine tuning the pasture calendar in respective Major Land Resource Areas (MLRA's) from year to year, around 360 GDD's F can be very useful in helping to determine when your grass species pastures and hay fields will be waking up in the Spring, based on thermal time, rather than calendar time. This growth period 5a (Chapter 6) would be occurring in the late winter or early spring, depending upon elevation.

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Appendix Chapter 13

Is Burning Irrigated Pastures and Hay Fields: A Good, Bad, or Indifferent Concept?

Mylen Bohle and Steve Fransen¹

There are reasons to burn and reasons to not burn a pasture. If you are planning to burn, make sure the proper authorities are notified, and the proper permits (if necessary) are in hand before “striking the match”. Make sure the proper and sufficient fire-fighting equipment is available and in place, just in case the fire escapes. An uncontrolled fire spreading onto the neighbor’s property or a burn down of your own buildings is not a great outcome.

If you are going to burn, burn cool, not hot, if possible. Rhizomatous plants will tolerate burning better than bunch grass species. Bunch grass species often have elevated growing points (apical meristems) positioning these grasses at a disadvantage with a hot fire compared to rhizomatous species who also have apical meristems, but are below ground.

Cool fires are influenced by more moisture in the soil, slight green up of plants, and high humidity, resulting in less damage to existing plants. Hot fires are influenced by dry soils, burning prior green-up, and low humidity, resulting in more damage to existing plants. The PNW cool season grasses are more sensitive to damage from fire than warm season grasses.

A cool fire would not have much-residual material on the field and has a breeze that is moving the fire across the field at a fair pace. A little warmer fire might be one with little to moderate residual material and not much of a breeze and moving across the field at a slow pace. An even warmer/hotter fire would be a moderate amount of material with a slower breeze moving the fire at a slower pace across the field. The hottest fire would be a lot of material on the field, with not much of a breeze moving the fire across the field at a slow pace.

If cheatgrass is growing in the field, and for control with fire to be effective, it would have to burn the plants while the seed is still attached to the plant. Once the seed drops to the soil surface (and for most plant seed), fires usually are not hot enough to dramatically damage the seed. This seed will still be there to germinate and infest the field again. Planting back into the field with beneficial species, depending upon many factors, can

fill in bare spots in the field, and create competition for the cheatgrass. Managing the field then through grazing, weed control, fertilization, and or clipping will decrease the amount of cheatgrass, and increase competition from beneficial species.

Grain fields with all of their straw left on the field will burn hotter in general than hay fields or pastures. That can have an effect on cheatgrass and some weed seeds.

Reasons to burn

- Clover mites can infest well-managed and fertilized orchardgrass, and other grass species hay fields and pastures and there are no labeled miticides / insecticides. To control these mites, burning the pasture or hay field in the late winter/early spring is the only option to try to control these mites. These mites can take out a field if populations are high enough, or at the very least, decrease yield dramatically on the first cutting of hay or spring pasture growth.
- Winter grain mites can infest well-managed orchardgrass, timothy, and other grass species hay fields and pastures as well as small grains, but there are insecticides/miticides labelled to control these mites. However, these mites produce two generations per year, fall and spring, so like the clover mite, pasture burning in late winter / early spring has shown population reductions of 60 - 70 %. These mites can dramatically reduce growth on the first cutting of hay or spring pasture growth.
- If there is a fair amount of aftermath growth that needs to be removed from the field, then either it has to be removed off the field mechanically (swath, rake and bale), or graze off, or burned, or chopped and let it decompose into the soil. With too much aftermath left, it can end up in the 1st cutting hay bales. Hay bales with some old aftermath mixed in with the new hay might not be so bad when feeding on farm/ranch as a better option, but when selling hay, then that is quite another story.
- Organic producers cannot use conventional pesticides for insect or mite control, so burning may be the only viable option. If you have legumes in the pasture like alfalfa or clover, other insects like aphids, or alfalfa weevil could be a problem. Insecticide application is out of the question. Then burning a field with a high population of insects damaging the legume and / or grass plants may be a great option.

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- Burning off aftermath does speed up the process of releasing minerals to the soil and making them available to the plants. Otherwise, the aftermath is decomposed slowly back into the soil, creating organic matter, and slowly releasing it's minerals. Of course, creating more organic matter from the litter, is a good thing and slowly increases soil health.
- Burning can remove some weeds. Fires have to really burn hot to damage seed that has fallen to the soil surface. Perennial weeds and weeds with rhizomes or stolons are much harder to control with fire than weedy bunchgrasses or fine annual grasses prior to dropping seedheads. A blackened soil surface, from burning a field, prior to planting, can warm the soil and may increase germination of seed when there is enough available moisture.
- Burning a field to stunt the perennial plants prior to no-till planting/interseeding a field with existing vegetation, may offer a little more time for the new seedlings to have less competition from the established plants, as they can out compete new seedlings for sunlight, water, and nutrients.
- Monitor the field after burning - the spots where it did not burn, those plants are taller than where the field was burned, as growth happens over time, even though it looked so nice and green, and clean, when regrowth started in the area that were burned. You might find that you will not want to burn the field as often as you have in the past.
- Burning a field will allow sunshine to hit the soil and speed up warming of the soil to increase plant growth, or so it seems. You now have burned off the carbohydrates and sugars in the crown area, which will slow down the growth or regrowth of the plants. As pastures green up, you may notice areas where the plants have not burned, and that they are actually ahead, growth wise, of the area that burned.
- Burning also burns off and volatilizes a little bit of potassium and sulfur, a little nitrogen, and of course, a fair amount of carbon, releasing it into the atmosphere. Thus, over the years, if fields are burned repeatedly, one may need to manage pasture soil fertility differently.

Reasons to Not Burn

- If the fire is too hot, then you can take out the weaker pasture plants and if done repeatedly over years, can shorten the life of the plant stand. Orchardgrass seems to be one species that is more sensitive. As stated before, bunchgrasses are more susceptible to hot fires than rhizomatous plants.
- The remaining top growth, after hay harvest or grazing (that 3 – 4 inch / 7.5 – 10 cm crown area above ground), is where the plants store their carbohydrates and sugars (very little is stored in the root, comparatively). Plants utilize those carbohydrates and sugars going through the winter and then to regrow in the spring. Roots shed starting in the late Fall and through Winter. Then in late winter / very early spring, the roots start regenerating themselves. Plants utilize these carbs and sugars until photosynthesis can fill the crown and root system back up again (sometimes not till 4th or 5th leaf stage of growth for grass species).
- If weeds or insects are a problem after burning, the release of the carbon can and will tie up the pesticide being applied. Higher application rates of pesticide may be needed, in order to compensate for the pesticide tie-up by the carbon.
- Burning will have a negative effect on organic matter. Burning aftermath bypasses the natural breakdown of the plant aftermath and conversion into organic matter. Organic matter, on the surface, can be burned up also, and therefore is further reducing organic matter content of the soil, which is the lifeblood of the soil.
- If burning a field, and then applying nitrogen fertilizer, you may/can volatilize a fair amount of nitrogen. With the loss of ammonium nitrate fertilizer and the use of urea fertilizers, it is important to use a coating that keeps the nitrogen from volatilizing, until at least a half inch of water is applied. Usually, the coating only prevents this from happening for about 30 days or so. Carbon increases the volatilization.

Summary: Burn only if you have reason to do so.

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Appendix Chapter 14

Grazing to Limit Wildfire

[†]Tip Hudson

The majority of the Inland Northwest receives low precipitation, sufficiently low to be classified as a semi-arid to arid ecoregion. The majority of precipitation arrives between October and April, during winter when plants are not actively growing. Dry, hot summers, combined with irrigation, enable high quality crop production, including forage crops such as alfalfa and grass hay and pastures. On non-irrigated lands, however, these weather patterns create fire-prone conditions on rangeland and dry forest types every year.

Today, fire frequencies are higher on many rangelands due to the influence of exotic invasive annual grasses (IAG) which displace natives and provoke a feedback loop in which more IAG causes larger and more frequent fires, decreasing perennial grasses and shrubs, leaving soil niches vulnerable to further invasion by IAG, increasing fire frequency, and the cycle continues. While non-native annual grasses are the reason for the feedback loop, the annual grasses were given a foothold in many places due to unsustainable grazing practices that prevailed during the late 1800s and early 1900s, practices which weakened native perennial grasses and decreased rangeland health. Grazing can be an effective biological control mechanism to limit the size and severity of wildfires. However, improper grazing can also create altered plant communities at higher risk of wildfire.

While there is much we don't know about the relationships among grazing, fire, and natural plant communities, a few things are plain. Fire requires fuel. Most fires start and are carried by fine fuels. Most of the vegetative species that constitute fine fuels are what livestock eat. Livestock grazing reduces the amount of standing biomass, at least temporarily, and if grazing occurs near the onset of summer dormancy (in the NW) this fuel reduction lasts into winter. But not all grazing is equal. Repeated heavy grazing, especially heavy spring grazing, effectively reduces herbaceous biomass; it can also convert otherwise fire-resilient plant communities into less productive, fire-prone plant communities that are prohibitively expensive to rehabilitate. Managing to sustain or perpetuate healthy plant communities is affordable under livestock production. Recovering a plant community that crossed an ecological threshold into a degraded stable state is not affordable with per acre profits possible in rangeland-based livestock production. Grazing management, then, must simultaneously hold

up the goals of promoting desirable perennial forage (and non-forage) species and suppressing undesirable species such as invasive annual grasses or weedy forbs that both lengthen and intensify the 'fire season'.

Invasive annual grasses such as cheatgrass, medusa-head, ventenata, and foxtail barley promote wildfire through three key mechanisms. First, IAG have lower moisture levels in the plant tissue when individual plants reach maturity. Second, where IAG is a dominant component of the plant community, the period of the year with low fuel moisture is much longer; this could be May-October in many locations, compared to August-September where perennials dominate. Third, IAG create greater fuel continuity. The shrub and perennial bunchgrass plant communities native to the inland Northwest naturally have empty interspaces between plants. When these interspaces fill up with IAG, the result is nearly solid flammable ground cover.

Humans can manage fire intensity by manipulating the kind and amount and continuity of vegetation. As a fine fuel management measure, grazing disturbs soil less than mechanical techniques for managing fuels and is less expensive. Careful grazing is also less expensive than chemical controls on vast acreages.

Yet in the 21st century, following many decades of multi-faceted research, many of the same questions remain as were being asked a century ago. "At present limited research knowledge exists to help guide manager in using grazing animals for fuel management . . . There is a lack of research knowledge upon which to draw in order to refine the grazing treatments to meet fuel management objectives." (Nader et al. 2007). It is safe to say that grazing can limit wildfire risk. But there are many facets to the concept of fire risk. Is it our goal to: Prevent all fire? Burn fewer acres in a single fire? Facilitate cooler fires? Prevent ground fires from becoming crown fires in forests? Limit fire in places with high populations of IAG to aid in recovering perennials?

Several general principles emerge from a review of the last century's grazing and fire research (Committee on Increasing Resilience to Wildland Fire: A Century of Wildland Fire Research et al. 2017). Grazing, even light grazing, by domestic livestock reduces the volume of fine fuels, disrupts the continuity of fine fuel, and increases the amount of contact between residual herbaceous material and the soil surface, which increases fuel moisture. These conditions can decrease fire size, increase fire patchiness, reduce flame height, and decrease wildfire frequency. These influences lower fire risk without necessarily causing degradation.

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Interestingly, Aldo Leopold, writing for the Forest Service in 1923, summarized his thoughts in four resolutions presented to a conference on fire protection. Much of what he wrote remains applicable:

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“There are areas on the national forests of high fire hazard, where this hazard can be greatly reduced through grazing. Distribution of stock to accomplish this should be undertaken in cases where there is now incomplete utilization, making such concessions as may be necessary to stockmen to introduce stock into inaccessible areas. Destructive grazing is not usually required to accomplish the desired purpose; due regard may therefore be given so as to furnish continuous annual range and stable grazing. Where studies or knowledge of local conditions indicated that desired timber reproduction would be prevented, forest growth injured, or watershed values impaired by the kind of grazing needed to reduce fire hazard, decisions must be reached on the basis of the best available data as to which is most important.” (quoted in Sayre 2017)

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The following principles, then, represent the state of the science in 2020 regarding grazing to limit wildfire and promote naturally-occurring perennial-dominated plant communities adapted to the INW climate:

1. Graze to maintain perennial grasses; perennial grasses increase both resistance and resilience to wildfire.
2. Cheatgrass increases fire frequency; graze to suppress seed production of undesirable annuals if this doesn't damage perennials.
3. Aggressively grazing perennial grass weakens its ability to compete and invites cheatgrass.
4. Grazing is not a 1:1 biological substitute for fire, but prescribed fire is risky for private landowners.
5. Reducing fine fuels reduces fire risk.
6. Grazing disrupts the continuity of surface fuel and, therefore, surface fire.
7. Grazing causes smaller fires, lower flame height, and slower rate of spread.
8. After fire, allow grasses to reach seed set before grazing, especially in the first 2-3 years post-fire.
9. Intensive grazing can be applied with any number of cattle; stocking rate is not irrelevant, but it's not everything.

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Appendix Chapter 15

Irrigation Resources for Pasture and Hay

Mylon Bohle and Glenn Shewmaker¹

Introduction

Water is an asset that is essential for the irrigated pasture and hay fields in the Inland Pacific Northwest. There are numerous pressures on increased water utilization by production agriculture, recreation, wildlife, industrial, and urban needs. There are 660,000 acres (267,000 ha) of irrigated pasture and hay in the Inland PNW. The last few decades have seen less snowpack, earlier melt of the snowpack, decreased Spring through Fall rain, and increased annual average growing season temperatures.

This has decreased availability of irrigation water in some areas and increased evaporation and transpiration during the growing season in the Inland PNW. Water to grow pasture and hay will need to be utilized in the most efficient way possible. Less water to grow the same crop will leave more water in stream and in rivers. Application of irrigation water in the most efficient way possible will reduce power bills – a great economic benefit. But if you

are short on water and can increase water use efficiency, then while there may not be a water or power savings, there can be an economic benefit from increased yield.

Some the resources below will help aid producers in looking at more water use efficient systems and management to really utilize their water resource in the most beneficial way. Agrimet water use program predicts daily water use for pasture and grass and alfalfa hay (link below). The WSU Irrigation Scheduler program is a great online tool to aid producers in managing water applications in a more scientific way (link below). Other resources will offer better management tips on using different irrigation delivery systems, among other useful information. The resources listed below are from the California, Idaho, Oregon, and Washington Extension Service programs and Bureau of Reclamation. These resources can make all of us better irrigators and utilize a precious water resource more efficiently.

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APPENDIX CHAPTER 16

Pasture Calendar Economics

J. Shannon Neiberger and Ashley Westerhold¹

Evaluating pasture economics is challenging due to the number of variable factors determining net economic return such as spatial variation in forage yields that are affected by temperature, precipitation and land quality as illustrated by the state MLRA maps previously provided in this publication. Pasture management activities such as fertilization and setting stocking rates are also variable factors that impacts forage yield this year but could also improve or reduce forage yield and quality in the future. For example, stocking rates above carrying capacity resulting in overgrazing this year could negatively affect pasture regrowth as well as increase weed competition reducing future pasture yields. Maximizing net returns from pasture resources is a complex task to account for forage growth biological principles and the unique attributions of the forage resource being managed. The purpose of this chapter is to discuss pasture calendar economics.

The Challenge in Measuring Pasture Yield

The basic economic principle guiding management decisions to purchase or invest in production inputs to the extent that marginal benefit exceeds marginal cost incorporating the law of diminishing returns. The law of diminishing returns as each additional unit of a production input is used there is less additional production for each additional unit of input used, up to a critical value beyond which there is no further response. Applying marginal economics in pasture management is challenging because determining marginal benefit requires measuring forage yield and quality. For almost all agricultural commodities, production yield pay weight is directly measured by weight scales or inventory count to calculate revenue. Wheat and corn yields are measured by weight and converted into bushels and multiplied by price to calculate producer revenue. Hay is typically weighed or occasionally sold by bale count. Cattle are sold by individual, pen or truckload weight. Accurate yield measurement provides a tool to improve management decisions that result in improved payweight and quality premiums.

There are tools to estimate pasture yield or cumulative forage growth. Hoops and plate techniques use a

spatial sampling technique where forage can be cut and weighed (Brence, L. and Sheley, 2003 <https://extension.usu.edu/behave/ou-files/economics-behavior/Estimating-Range-Production.pdf>). A pasture stick provides a tool to measure grass height as a means to estimate forage stand condition, (<https://forages.oregonstate.edu/fi/pasture/stand-evaluation>). These tools provide a means to assess pasture productivity and quality that can be used to set stocking rates. Although stocking rates are a direct factor in calculating pasture revenue they are not a direct measure of pasture yield and quality. Stocking rates and pasture quality affect animal condition which adds an additional variance factor when evaluating pasture management.

Pasture Value of Production

The marginal benefit to pasture management depends on if the revenue generated from the pasture is rent only or through gains from animal production. Consider the following pasture revenue equations:

1. Pasture Revenue = Stocking Rate * \$/AUM * Grazing Period in months
2. Pasture Revenue = Stocking Rate * (Market Price \$/lb * Animal Gain or Production)
3. Pasture Revenue = Stocking Rate Breeding Animals * ((Market Price \$/lb * Weaned Animal Gain) + Dam Maintenance Cost)

In equation 1, pasture revenue is a fixed rental rate per animal, \$/AUM multiplied by the stocking rate and the number of months in the grazing period. In equation 2, pasture revenue is based on the market value or price times the amount of animal gain or production. This equation reflects the economic situation of a beef cattle stocker operation, a grass finished beef operation, or a pasture dairy operation where animal nutrition is primarily provided by the pasture and revenue is directly based on animal production. The third equation reflects breeding animal operations where the revenue generated is from the sale of weaned animal production, but also provides a non-cash economic return to pasture for the dam nutrition maintenance cost that is provided by the pasture over the grazing period. This reflects the assumption that nutrition costs would have to be provided by purchased feed if the pasture was unavailable.

In each equation the stocking rate is the major factor affecting potential pasture revenue. The importance of stocking rates stems from the relationships presented in Figure 1 which shows the marginal production effect of increasing stocking rates on animal production gain

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and animal production per acre of pasture. Production per acre reflects the total weight gain. As the stocking rate increases total gain continues to increase even after production per animal begins to decrease. With higher stocking rates animals become crowded enough that total gain decreases. Both curves in Figure 1 reflect the law of diminishing returns where production increases to a maximum point and then falls. Peak animal production occurs at a lower stocking rate than maximizing production per acre (Wachenheim, C.J. et al., 2000, J. Anim. Sci. 2000. 78:2209–2214 <https://doi.org/10.2527/2000.7882209x> and Gray W. and M. Bohle, 2010, PNW 614 <https://www.extension.uidaho.edu/publishing/pdf/pnw/pnw0614.pdf>). This reflects the tradeoff between managing pasture for optimal rates of gain for peak animal performance versus maximizing the economics when renting pasture and seeking returns to the land asset from the perspective of the land owner or a fixed expense from the perspective of the pasture rent lessee. Both economic relationships show the incentive to increase stocking rates up to the point of diminishing returns as a means to maximize economic goals. When managing pasture for gain, a lower stocking rate and investing in pasture inputs to maximize rates of gain, guide management decisions. However, because of temporal and spatial variation in quantity and quality of forage as presented the MRLA maps, the optimal stocking rates required to maximize production/unit-area of land varies.

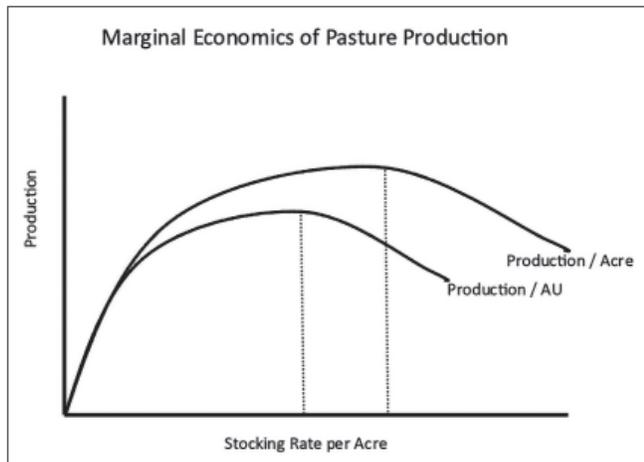


Figure 1 Marginal Economics of Pasture Production

Managed grazing systems is a specific application of marginal economic principles. Managed grazing systems by design subdivides a pasture resource using temporary or permanent fencing to increase stocking rate to increase grazing intensity with the goals to increase pasture productivity and pasture utilization to support increasing the stocking rate and animal productivity. The economic goal is that the marginal benefit from increased pasture productivity is greater than the marginal cost of increase

Table 1. 2019 Washington Feeder Cattle Prices May to July

Weight	May	June	July
	\$/cwt		
6-700	\$151.98	\$143.50	\$144.76
7-800	\$137.10	\$133.00	\$132.52
8-900	\$126.01	\$128.00	\$134.06

Source: https://www.ams.usda.gov/mnreports/LSD_MARS_2132.pdf

labor and fencing costs. The net economic gain will be unique to each operation implementing a managed grazing system because of the unique opportunity cost of labor, herd productivity and the variation in pasture quality as indicated by the MLRA maps.

Price Slide

Compounding the complexity of managing pasture economics is that animal market price in equations 2 and 3 decreases as animals gain weight. This is referred to as a price slide. As a producer manages animal productivity relative to stocking rate, the producer also has to manage the price slide market disadvantage. Table 1 shows the price slide for May June and July using Washington feeder cattle prices using data from 2019 reflecting a period of time where stocker operations would market cattle that would typically be purchased and placed into a feedlot. The price slide is that revenue (price * weight) increases as animals get larger, but the price per cwt declines and that the weight price breaks introduce price risk.

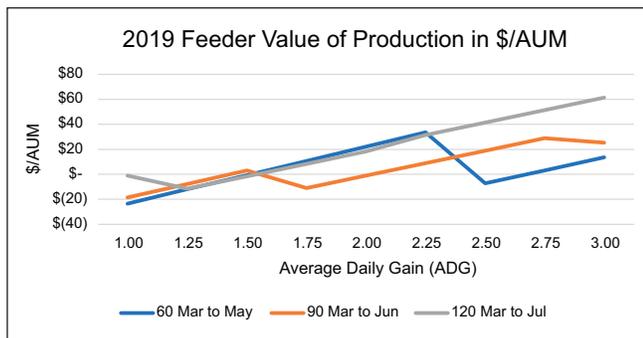
In addition to the monthly seasonality for each weight group, Table 1 shows that the average price slide across the 100 pound-(45 kg) weight groups was about -\$8.69. The price slide is different for each year and across months as market conditions change. The price variation in Table 1 shows price declines for each weight group, except for July where the price for 800-900 pound (363-408 kg) cattle increased \$1.54 per cwt.

A price slide value of production scenario analysis is presented in Table 2. The scenario costs assume that stocker cattle are purchased in March weighing 550 pounds (249 kg) at a price of \$171.23 per cwt, health cost was \$8 per head, labor \$10 per head, salt, and minerals \$3 per head, marketing costs \$9 per head for brand inspection, checkoff and transportation, and \$2 per head miscellaneous cost.

The value of production per head is calculated using the ADG to calculate weight sold at the end of the grazing period and prices from Table 1 minus the assumed costs of production detailed above and the purchase cost. Three grazing periods are analyzed. Table 2 shows that ADG needs to be above 1.5 pounds (680 g) per day to generate positive value of production,

Table 2. Grazing Value of Production Scenario Analysis

	Days Grazed		
	60	90	120
ADG	Mar-May	Mar-Jun	Mar-Jul
1.00	-\$46.69	-\$55.36	-\$3.87
1.25	-\$23.89	-\$23.08	-\$46.12
1.50	-\$1.09	\$9.21	-\$6.37
1.75	\$21.70	-\$32.79	\$33.39
2.00	\$44.50	-\$2.87	\$73.14
2.25	\$67.30	\$27.06	\$125.53
2.50	-\$14.07	\$56.99	\$165.75
2.75	\$6.50	\$86.91	\$205.96
3.00	\$27.06	\$75.83	\$246.18

**Figure 2.** Potential AUM Values Based on Value of Production Scenarios.

but also identifies cases of price slide risk. For example, ADG of 1.75 (794 g) and the 90-day grazing period shows a value of production loss of -\$32.79 per head and ADG of 2.5 (1134 g) and a 60-day grazing period shows a loss of -\$14.07 per head due to price slide risk.

Table 2 value of production per head does not include the pasture cost. It represents returns to pasture and management profit and other unaccounted expenses such as death loss risk which is not accounted for in the scenarios. To present potential returns to pasture the value of production was converted to a \$/AUM value based on the grazing period and is presented in Figure 2. These AUM rates reflect the maximum breakeven rates a producer could pay given the assumptions of these stocker grazing scenarios. The \$/AUM rental rate is commonly used in reporting pasture value and pasture rental contracts for both public and private pastureland. Figure 2 illustrates that a minimum ADG of 1.5 (680 g) is needed to generate returns to pasture costs, and also importantly illustrates the high value of pasture with ADG above 2.0 (908 g). Well managed pasture grazing

Table 3. Pasture Cash Rents \$/AUM

	Idaho	Oregon	Washington
	\$/AUM	\$/AUM	\$/AUM
2019	\$18.00	\$18.50	\$14.50
2018	\$18.00	\$17.50	\$14.50
2017	\$18.00	\$16.50	\$14.00
2016	\$18.00	\$17.00	\$14.00
2015	\$17.00	\$16.50	\$13.00
2014	\$16.50	\$17.00	\$13.50

www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Cash_Rents_by_County/

systems have the potential to generate high economic returns.

The AUM values provided in Figure 2 can be put into perspective using pasture cash rent values reported by the USDA. Table 3 provides AUM rental rates for Idaho, Oregon and Washington from 2014 to 2019. Current AUM rates in Oregon and Idaho are similar at about \$18 per AUM and Washington is lower at \$14.50 per AUM. The AUM rates have low variation over the six years reported in Table 3 and indicate that AUM rates are slow to respond to economic conditions. Beef cattle prices set historic records in 2014 and into 2015. If pasture rents reflected economic conditions then those years should have had relatively higher rent values. The AUM rates in Table 3 exhibit what economists call sticky prices where prices are resistant to quick changes despite shifts or changes in economic conditions. A factor contributing to pasture rent price stickiness is that pastures are rented by the same entity over many years under a private contract and pasture in general lacks a market structure that facilitates competitive price bidding.

Seasonal Economics

Supply and demand are a fundamental economic principle that applies to pasture economics but is not well reflected by sticky market prices for AUM rental rates. Most agricultural commodities have seasonal price variation over the year reflecting supply and demand pricing. At harvest, supply is at a peak and prices are lower and then vary across the year as harvested supply is stored to meet demand over the year, commonly applied in apples and potatoes, for example. In pasture management, storage is called stockpiling where the grazing plan selects pastures that will be grazed later in the summer and fall outside of the peak of the forage growth curve. Stockpiled forages can extend the grazing season for several more months and reduce the amount of hay needed to supplement pasture provided nutrition. The quality or forage nutritional content of stockpiled forage varies by plant

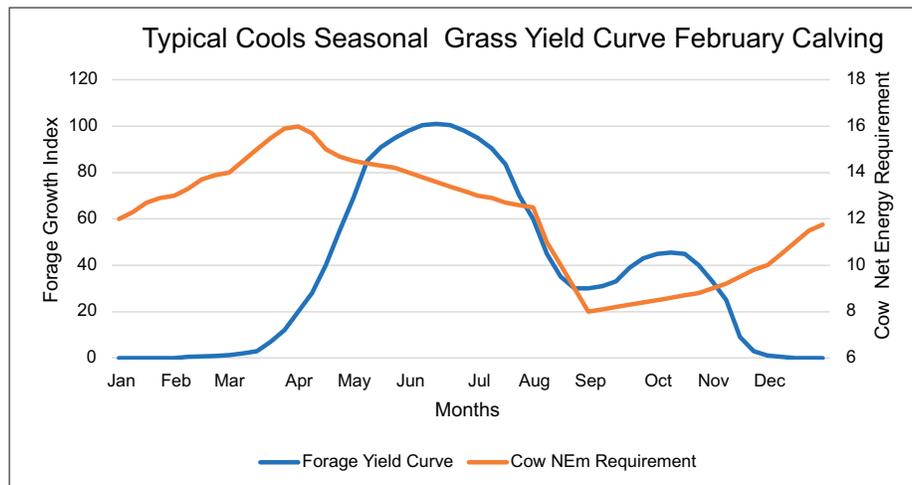


Figure 3. Typical Perennial Cool-Season Grass Yield Curve and 1,200 Pound Beef Cow Energy Demand (Author calculations).

species. The quantity of forage across the year could be considered the supply.

Animal nutrition requirements vary across the year with peak nutritional demand for breeding animals occurring in late gestation and lactation. Pasture management needs to provide nutritional resources through pasture and supplementation if needed. Previous chapters in the Pasture Calendar have shown the seasonal forage growth curve that is presented again in Figure 3 with the forage growth represented on the left axis representing supply of forage. Beef cow nutritional requirements vary across the year and beef cow demand for energy is represented the right axis based on a February calving date.

Cool-season forages fluctuate in growth over the year having a high growth rate in the spring and a lower growth rate in the summer, some fall growth and a dormant winter period. This occurs since cool-season forages grow best when they have long days, relatively cool weather, and adequate soil moisture. These three environmental conditions are typically most conducive to highest forage growth in May and June. Pasture management strategies to balance supply and demand include:

- Timing the livestock production cycle to the forage production cycle by choosing breeding intervals that balance forage growth and animal growth.
- Making hay from excess production and grazing crop aftermath growth.
- Fertilization to enhance forage growth and quality to enhance forage supply and quality of stockpiled forage.
- Varying the stocking rate by through flexible animal inventory management using selling or buying animals.

- Feeding supplemental nutrition to balance forage provided nutrition with animal needs to maximize animal production efficiency.
- Manage acceptable changes in animal rate of gain or body condition.

A theoretical supply and demand model for pasture is presented below. Specifically, the equation is called an inverse demand function where price is a function of quantity supplied and related demand factors. A time factor is included as the t subscript to discuss seasonal supply and demand characteristics.

$$AUM_t = fn((\text{Forage availability}_t * \text{Forage nutrition}_t) + \text{Animal nutrition demand}_t + \text{Space}_t + \text{Pasture amenities}_t)$$

The time subscript t represents months from 1 to 12 to correspond to the AUM rate and is the price paid or received for the pasture resource. Forage availability represents the supply of forage growth and stockpiling over the year and is adjusted by forage nutrient content and would reflect weather risk in forage growth. The combination of these two factors largely determines stocking rate. Animal nutrition demand represents the energy, protein and animal nutrition requirement that varies over the year. Space is a factor not widely discussed in pasture systems. Animals require a space to be. For breeding animals space is required year around and under certain conditions it could be a significant demand factor. For example, wildfire is an unpredictable risk and if it occurs animals may need to be relocated out of the fire effected area and producers may be forced to pay a premium for space to maintain their herd. Space is also a factor for the winter months. Over the winter months

a management concern is not only the amount of nutrients if any provided by the winter pasture or dry lot, but the space required to efficiently provide supplemental feed and manage the animal herd. Pasture amenities reflect fences, water systems, corrals, access, and size for example. Pasture size is not often discussed in pasture management literature, but large pastures are relatively rare and represent a potential premium value, so an animal herd doesn't have to be broken up across pasture units and the potential for increased flexibility in grazing management plans.

These demand model factors clearly collectively impact pasture value but the pasture market value does not reflect this variability. As presented in Table 3, AUM rates have sticky prices that do not vary over the year and shows little variation across the years. This mismatch identifies a future opportunity to develop a competitive pasture market structure that better accounts for pasture variation and productivity. A challenge in developing a new market structure is historic use of long-term grazing contracts that serve to reduce competition and price variation.

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Conclusions

Pasture enterprises have substantial production risk from weather conditions impacting forage growth and price risk affecting animal production returns. A challenge facing pasture managers is the unique attributes of each pasture concerning forage growth potential and timing of forage growth. It is becoming more common to truck animals to spatially distant pasture resources to take advantage of timing differences in the pasture forage growth potential. Alternatively grazing operations manage forage growth cycles using stockpiling and grazing management plans. A challenge to evaluating pasture economics is the difficulty in accurately measuring pasture production. Returns to pasture are also a challenge. AUM rates typically do not reflect variation in pasture quality, or returns are based on animal production gains which are difficult to capture and report. Pasture economic risk can be reduced by establishing forage diversity across the pasture, by having planned flexibility in moving livestock in a grazing management plan, and by managing the forages and livestock appropriately based on life cycle stages. By using these biological and economic principles the pasture manager can optimize returns from pasture-raised livestock.

APPENDIX CHAPTER 17

Role of Insurance in Inland Pasture Management

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Introduction

Insurance has been used as a risk management tool for many years, mostly to insure against production risk. If there is no production because of something out of the control of the farmer/rancher, they should be compensated for their loss. In this case, a farmer/rancher would pay a premium to get a policy and then if an adverse event happened, they would be compensated with an indemnity. Over time, premiums should equal indemnities.

Unfortunately, pastureland acres did not have specific insurance programs specifically for them. Depending on conditions, pastureland could be insurable under Noninsured Crop Disaster Payments (NAP). However, in 2007, that all changed with the introduction of the Risk Management Agency (RMA) Pasture, Rangeland and Forage Insurance (PRF) as a pilot program providing livestock producers insurance for their loss of grazing or hay land dependent on either a rainfall index (RI) or vegetation index (VI). In 2016, RI-PRF replaced VI-PRF for all 48 contiguous states. In the 2014 Farm Bill, the government additionally provided mandated livestock disaster assistance programs to help manage feed losses. The Livestock Forage Program (LFP) provides feed assistance payments due to effects of drought or wildfire on grazing lands.

RI-PRF and disaster programs, while similar in that they provide financial assistance to producers' stemming from similar events, they help in fundamentally different ways. First, disaster assistance programs calculate payments based on ex-post disaster conditions taking into account multiple conditions that may contribute to drought, such as heat and precipitation. RI-PRF insures against upcoming production uncertainty insuring only a single peril, precipitation. Second, government mandated disaster assistance is 100% subsidized (zero producer paid premium), compared to RI-PRF which is subsidized between 51-59% based upon coverage level.² RI-PRF allows producers to choose their contract specificity and with the ability of choice, they are subject to pay higher premiums. Finally, RI-PRF is insuring precipitation based on a rainfall index from a 17-mile by 17-mile grid, while

LFP is based on the entire counties drought classification. Disaster payments are affected by county size since the drought index is based on county level. County size and location can cause regional differences in disaster assistance payments and size of payments for producers.

RI-PRF Program

RI-PRF represents a single peril index insurance product focusing on the production of perennial forages on rangeland, pastureland, and cropland. The objective of RI-PRF is to provide perennial forage producers revenue due to losses in precipitation (USDA-RMA 2017a). To be eligible for RI-PRF, the producer is required to have a share on insurable acreage that was in production before July 1, prior to the coverage year. RI-PRF offers a variety of contracts based on varying coverage levels and productivity factors. Coverage levels are chosen from 70%-90% in 5% increments varying by county and production type. Productivity factors vary from 60% to 150% of county base value in 1% increments.

RI-PRF insures by grids created by the National Oceanic Atmospheric Administration Climate Prediction Center and do not follow geopolitical boundaries. The gridded precipitation data represents an interpolated value based on the entire grid and cannot be traced to a single point or reporting station. RI-PRF requires the producer to insure monthly precipitation using two-month intervals. RI-PRF is available for the entire calendar year and not only during the grazing or haying season. Losses are calculated based on whether the current year's precipitation in a grid has deviated from the historical normal precipitation in the same grid, for the same interval. The 70% and 75% coverage levels are subsidized at 59% of the premium. For coverage levels of 80% and 85%, 55% of the premium is subsidized. Lastly, for 90% coverage level, 51% of the premium is subsidized.

The two-month interval rule results in eleven insurance intervals during the calendar year: January-February, February-March, March-April, April-May, May-June, June-July, July-August, August-September, September-October, October-November, and November-December. RI-PRF rules require that producers must insure at least two intervals and intervals cannot overlap (i.e., cannot insure January-February interval and February-March interval) effectively limiting the maximum number of intervals to six. Intervals are weighted with a minimum weight of 10% and a maximum weight of 60% requiring the sum of weights to add up to 100%. Losses are calculated based on whether the current year's precipitation in a grid has deviated from the historical normal

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²To sign up for LFP, the producer must go to their FSA office and sign up for the program. This could be considered a cost, but the producer paid premium is zero.

Table 1. Rainfall Index (RI-PRF) Policies Enrolled Producer Paid Premiums, Indemnities, Loss Ratio, and Returns from Insurance (Indemnities-Producer Paid Premiums) per Acre

State	Year	Acres	Producer Paid		Loss Ratio	Returns/Acre
			Premium	Indemnity		
Idaho	2016	51,207	226,264	576,961	1.21	6.848614447
	2017	117,607	401,784	343,242	0.4	-0.497776493
	2018	692,342	1,398,262	4,751,175	1.59	4.842856565
	2019	1,937,504	4,595,833	11,117,384	1.12	3.365954857
	2020	3,731,900	9,586,441	19,873,512	0.96	2.756523755
Oregon	2016	432,656	1,299,353	2,456,597	0.86	2.674743907
	2017	706,361	2,050,949	3,725,284	0.83	2.370367277
	2018	2,260,716	4,440,160	17,026,068	1.74	5.567222066
	2019	5,507,323	11,115,629	25,138,041	1.03	2.546139386
	2020	7,405,586	15,814,692	52,739,687	1.53	4.986100357
Washington	2016	74,357	393,708	771,845	0.96	5.085425716
	2017	297,215	1,266,204	3,825,889	1.47	8.612233568
	2018	405,520	2,012,444	8,327,919	2	15.57376948
	2019	758,736	3,490,889	7,117,487	0.98	4.779789018
	2020	2,137,507	10,380,774	21,478,889	1	5.192083581

Note: United States Department of Agriculture Risk Management Agency Summary of Business Reports of RI-PRF between years 2016-2020 (most current data) for Idaho, Oregon, and Washington.

precipitation in the same grid, for the same interval. An indemnity will be paid if

1. Payment calculation factor = (Trigger grid index – Final grid index) / Trigger grid index > 0

where the trigger grid index is equal to the insured's coverage level multiplied by the expected grid index and the final grid index represents NOAA's interpolated current year gridded precipitation data or successor data for each grid ID and index interval (USDA-RMA 2021). Expected grid index or expected precipitation is the mean accumulated precipitation by both grid and insurance interval, calculated using NOAA's interpolated historical gridded precipitation or successor data and expressed as a percentage with mean equal to 100 (USDA-RMA 2021).

The size of the indemnity depends upon the size of the policy protection per unit –calculated as

2. Policy protection per = insured acres * producer share * dollar amount of protection

where insured acres identify the size of the insured area, producer share identifies the forage share belonging to the producer, and dollar amount of protection is calculated as

3. Dollar amount of protection = county base value * productivity factor * coverage level

where county base value represents the forage value in the county and is determined by the RMA (USDA-RMA 2021).

Indemnity is then calculated as

4. Indemnity = payment calculation factor * policy protection per unit

RI-PRF has had many years with positive returns per acre for all the PNW states as shown in Table 1. Since the program is subsidized, producers were able to have larger returns per acre. Only in Idaho in 2017, did producers lose almost \$.50 per acre. The loss ratio explains how the insurance policy is doing. If the loss ratio is 1, that means premiums paid = indemnities. If the ratio is larger, it means more indemnities were paid than premiums, where the ratio is smaller, it means more premiums were paid over indemnities. Since the insurance program is subsidized between 51%-59%, the loss ratio would need to be below that for the producer to lose their premiums paid.

Livestock Forage Program

LFP is a disaster assistance program to compensate livestock producers who have suffered grazing losses for covered livestock on land that is native or improved pastureland with permanent vegetative cover or is

planted specifically for grazing (USDA-FSA 2021). The grazing losses must be due to a qualifying drought condition during the normal grazing period for the county. An eligible livestock producer would be a producer who owns or leases grazing land or pastureland physically located in a county where the U.S. Drought Monitor declared the county to be within D2-D4 drought intensities (USDA-FSA 2021).

D2 intensity is defined as a severe drought where the crop or pasture losses are likely, water shortages common, and water restrictions imposed (USDAM 2017). If any area of the county is in D2 for at least eight consecutive weeks during the normal grazing period, the county is eligible to receive assistance in an amount equal to one monthly payment (USDA-FSA 2021).

D3 intensity is defined as an extreme drought where crop and pasture losses would be major, widespread water shortages and restrictions (USDAM 2021). If any area of the county is in D3 at any time during the normal grazing period, the county is eligible to receive assistance in an amount equal to three monthly payments. If any area in the county has a D3 drought for at least four weeks during the normal grazing period, the county is eligible to receive assistance in amount equal to four monthly payments (USDA-FSA 2021).

D4 intensity is defined as an exceptional drought to which there are exceptional and widespread crop/pasture losses, shortage of water in reservoirs, streams and wells creating water emergencies (USDAM 2021). If any area of the county is in a D4 during the normal grazing period, the county is eligible to receive assistance in amount equal to four monthly payments. If there is D4 in a county for four weeks during the normal grazing period, the county is eligible to receive assistance in amount equal to five monthly payments (USDA-FSA 2021).

FSA created the LFP payment rate for drought which is equal to 60 percent of the lesser of either the monthly feed cost for all covered livestock owned or leased by an eligible livestock producer or calculated by using the normal carrying capacity of the eligible grazing land of the eligible livestock producer (USDA-FSA 2021). Total LFP payments to an eligible livestock producer in a calendar year for grazing losses does not exceed five monthly payments for the same livestock. If an eligible livestock producer sold or otherwise disposed of livestock because of drought conditions in one or both two previous production years immediately preceding the current production year, the payment rate will equal 80 percent of the monthly payment rate. No one person

Table 2. Livestock Forage Disaster Program (LFP) Payments Over Time by State

Year	Idaho	Oregon	Washington
2012	\$1,802,736.00	\$17,469,509.00	\$0
2013	\$11,979,813.00	\$21,325,215.00	\$0
2014	\$10,443,673.00	\$31,419,811.00	\$1,754,148.00
2015	\$14,362,931.00	\$36,123,440.00	\$12,802,391.00
2016	\$2,646,396.00	\$5,668,022.00	\$853.00
2017	\$160,304.00	\$147,640.00	\$0
2018	\$0	\$25,446.00	\$0

Note: United States Department of Agriculture Farm Service Agency Reported Livestock Forage Payments between years 2012-2018 (most current data) for Idaho, Oregon, and Washington.

or legal entity may receive more than \$125,000 total in payments in all disaster assistance programs combined (USDA-FSA 2021).³ To sign up for the program, the eligible livestock producer must go to their local FSA office within 30 days of qualifying drought conditions to fill out paperwork.

Table 2 shows the LFP payments paid out to the different states over time. Idaho and Oregon have qualified or taken advantage of the program more than Washington according to the numbers.

PNW Example

[A] As shown, a rancher in Baker County, Oregon insured 100 acres of his grazing lands in RI-PRF for the summer of 2018. He insured at the 90% coverage level, splitting the coverage between May-June interval and July-August interval knowing that they let their cattle go out and graze from May through August. It was a rough summer in Baker County in 2018. Low snowpack and low precipitation caused it to be declared a D2 drought by the US Drought Monitor. Rainfall was 82.9% of normal in May-June interval and 10.7% of normal in the July-August interval. Using the indemnity support tool on the USDA RMA website, the rancher would have received \$12.61 per acre indemnities when only paying \$2.83 per acre in premiums (Table 3). Additionally, Table 3 shows the premium rates on the interval selections. Premium rates of July-August interval are \$30 per \$100 of coverage, where May-June is only \$13 per \$100 of coverage. This is because the July-August interval pays out more often. The more often an interval pays out and dependent on their payments, the premiums have to increase to get to the market where premiums = indemnities over time.

Since Baker County was in a qualifying D2 drought for 8 consecutive weeks, they qualified for one monthly disaster payment. The rancher would receive \$28.07 per head if adult cows or \$21.05 per head non-adult cows. With these two programs, it cannot be compared apples

³These disaster assistant programs include Livestock Indemnity Program (LIP) and Emergency Assistance for Livestock, Farm Raised Fish and Honeybees (ELAP).

Table 3. Rainfall Index Insurance for Pasture, Rangeland, and Forage Insurance Protection Information for PNW Example

Intended Use	Coverage Level	Productivity Factor	Insurable Interest	Insured Acres	Sample Year
Grazing	90%	100%	100%	100	2018

Note: USDA RMA Decision Tool Information using Baker County, Oregon, Grid ID 29147
<https://prodwebnlb.rma.usda.gov/apps/prf#>

Table 4. Rainfall Index Insurance for Pasture, Rangeland, and Forage Insurance Protection Table for PNW Example

Interval Code	Percent Of Value	Policy Protection Per Unit	Premium Rate Per \$100	Total Premium	Premium Subsidy	Producer Premium	Actual Index Value	Indemnity
Jan-Feb	0	\$0	\$14	\$0	\$0	\$0	81	\$0
Feb-Mar	0	\$0	\$14	\$0	\$0	\$0	94.6	\$0
Mar-Apr	0	\$0	\$14	\$0	\$0	\$0	117.2	\$0
Apr-May	0	\$0	\$14	\$0	\$0	\$0	87.5	\$0
May-Jun	50	\$1,314	\$13	\$175	\$89	\$86	82.9	\$104
Jun-Jul	0	\$0	\$22	\$0	\$0	\$0	66.3	\$0
Jul-Aug	50	\$1,314	\$30	\$401	\$204	\$197	10.7	\$1,158
Aug-Sep	0	\$0	\$26	\$0	\$0	\$0	10.9	\$0
Sep-Oct	0	\$0	\$20	\$0	\$0	\$0	60.7	\$0
Oct-Nov	0	\$0	\$17	\$0	\$0	\$0	75.7	\$0
Nov-Dec	0	\$0	\$16	\$0	\$0	\$0	89.2	\$0
Total	100	\$2,628		\$576	\$293	\$283		\$1,262

Note: USDA RMA Decision Tool Information using Baker County, Oregon, Grid ID 29147
<https://prodwebnlb.rma.usda.gov/apps/prf#>

Table 5. Rainfall Index Insurance for Pasture, Rangeland, and Forage Insurance

Total Premium	Premium Subsidy	Producer Premium	Indemnity
5.76	2.94	2.83	12.61

Note: USDA RMA Decision Tool Information using Baker County, Oregon, Grid ID 29147
<https://prodwebnlb.rma.usda.gov/apps/prf#>

Table 6. Rainfall Index Insurance for Pasture, Rangeland, and Forage Insurance Policy Information

County Base Value	Dollar Amount of Protection	Total Insured Acres	Total Policy Protection	Subsidy Level	Maximum Percent of Value Per Index Interval
29.2	26.28	100	2628	51.00%	70.00%

Note: USDA RMA Decision Tool Information using Baker County, Oregon, Grid ID 29147
<https://prodwebnlb.rma.usda.gov/apps/prf#>

to apples as indemnities are based on different criteria. RI-PRF is a payout per acre insured, where LFP is paid per head of cattle. This rancher would have received money

from both programs. Look at Tables 3, 4, 5, and 6 to see the USDA RMA decision support tool information showing the policy information.

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Appendix Chapter 18

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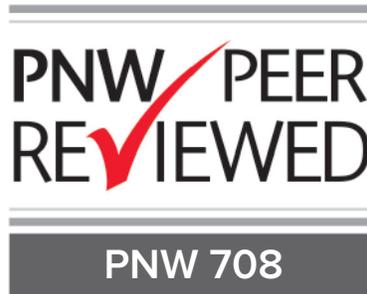
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