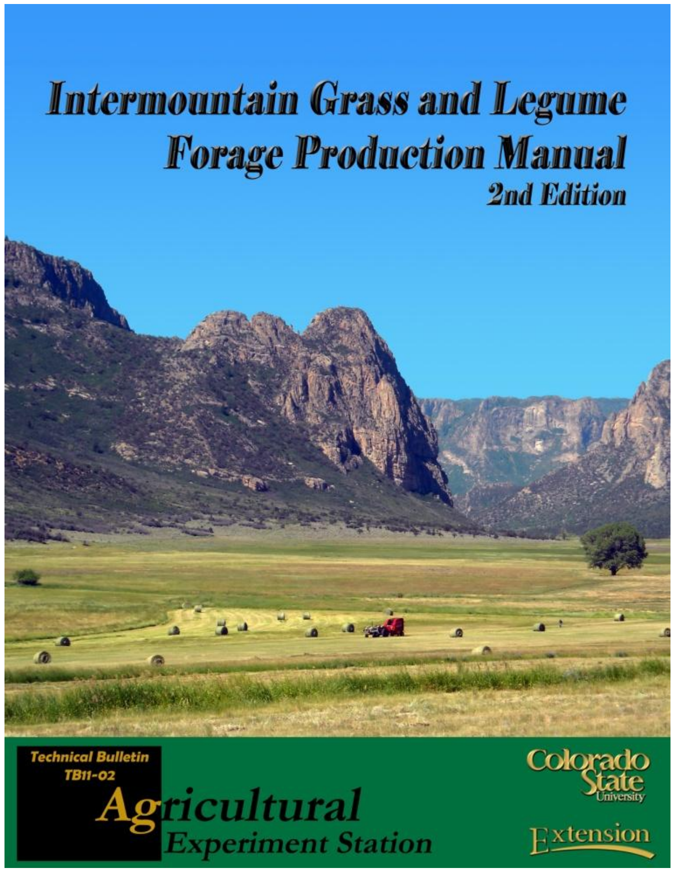

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Section I

Irrigated Pasture/Mountain Meadows

Chapter 7

Irrigation Management

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Introduction

Irrigated grass hay and pasture is an important forage resource for livestock producers throughout the intermountain region. In Colorado, grass hay was produced on approximately 750,000 acres in 2009 (Meyer and Ott, 2010). Nearly all of this land relies on good irrigation management to ensure maximum productivity, water conservation, salinity mitigation, and labor and time savings. Additionally, in certain areas of western Colorado, selenium contained in the Mancos shale underlying many fields is mobilized by deep percolation from over irrigation. Several streams, rivers, and lakes in western Colorado have selenium levels in excess of standards acceptable for aquatic life (CDPHE, 2007). Enhanced irrigation management, which includes improved application efficiency and uniformity, combined with irrigation scheduling for the correct timing and amount can help mitigate salinity, selenium, and other water quality problems.

Water Requirements

Water requirements for grass and other crops are determined by weather conditions and soil moisture available for plant uptake. Water requirements are typically described by the term evapotranspiration or ET, which is the combined water loss from the processes of evaporation and transpiration. The cumulative amount of ET for a crop over an entire growing season is roughly equivalent to that crop's seasonal water requirement. ET losses in a given area can be accurately predicted from measurements of four local weather variables: temperature, solar radiation, humidity, and wind. These weather variables differ significantly due to latitude and elevation which results in varying amounts of potential ET by grass pasture (Table 1a and b).

Grass pasture and hay yield increases with increased applied water, but the rate of yield increase varies with location and species. For example, in a study conducted by Smeal, et al. (2005) in northwestern New Mexico, meadow brome, orchardgrass, and tall fescue produced approximately 300 pounds of dry forage for each inch of water from irrigation and precipitation (Fig. 1). The rate of yield increase in wheatgrasses and perennial ryegrass, however, was much lower.

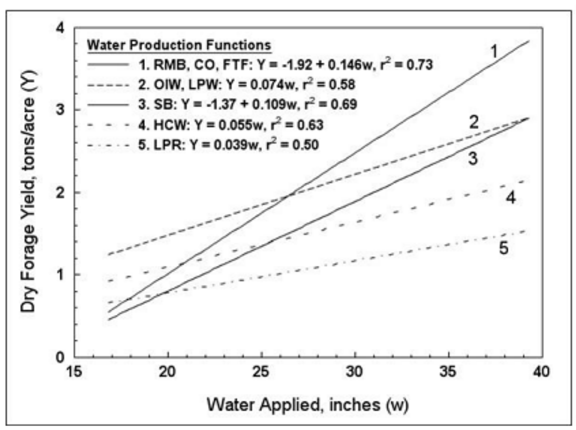

Fig. 1. Dry forage yield as affected by water applied for five grasses: (RMB) meadow brome; (OIW, LPW) intermediate pubescent wheatgrassses; (SB) smooth brome; (HCW) crested wheatgrass; and (LPR) perennial ryegrass.

Table 1a. Monthly and seasonal pasture grass water use requirements for selected locations in western Colorado (USDA/NRCS, 1988).

Location (Colorado)	March	April	May	June	July	Aug.	Sept.	Oct. + Nov.	Total ET
	---------- Average Consumptive Use (inches of water) ----------								
Cortez	0.2	1.6	3.0	4.5	5.7	5.0	3.2	1.7	24.7
Delta	0.6	2.3	4.0	5.6	6.8	5.8	3.8	2.0	30.8
Durango	0.1	1.6	2.8	4.0	5.3	4.7	3.0	1.7	23.2
Fruita	0.6	2.3	4.0	5.7	7.1	6.0	3.8	1.9	31.4
Glenwood Springs	0.3	1.8	3.3	4.8	6.1	5.2	3.4	1.5	26.4
Gunnison	0.0	0.5	2.2	3.5	4.4	3.8	2.4	0.3	17.1
Meeker	0.1	1.3	2.5	3.6	5.3	4.6	2.8	1.1	21.4
Monte Vista	0.0	1.0	2.3	3.9	4.8	4.9	2.7	1.0	20.6
Norwood	0.0	0.6	2.7	4.0	5.1	4.4	2.8	0.9	20.4
Walden	0.0	0.0	1.9	3.0	3.9	3.2	1.7	0.0	13.6

Table 1b. Pasture grass net irrigation requirements for selected locations in western Colorado (USDA/NRCS, 1988).

Location (Colorado)	Latitude and Elevation	Total ET	Ave. Effective Precipitation	Net Irrigation Requirement
			------inches of water------	
Cortez	37.225°/6,015’	24.7	5.4	19.6
Delta	38.734°/5,010’	30.8	4.1	26.8
Durango	37.283°/6,550’	23.2	8.3	14.8
Fruita	39.167°/4,500’	31.4	4.0	27.5
Glenwood Springs	39.544°/5,810’	26.4	7.6	18.8
Gunnison	38.544°/7,700’	17.1	3.8	13.3
Meeker	40.051°/6,400’	21.4	6.2	15.2
Monte Vista	37.581°/7,665’	20.6	3.9	16.6
Norwood	38.131°/7,010’	20.4	6.1	14.4
Walden	40.730°/8,110’	13.6	3.0	10.6

Some grasses are better suited for non-limiting water conditions and others perform better when water is short. In the New Mexico study for example, orchardgrass, meadow brome, and tall fescue produced more forage at higher irrigation levels than wheatgrasses (intermediate and crested), but the wheatgrasses yielded better when water was limited. Studies conducted in Utah found that meadow brome out yielded orchardgrass under limited irrigation (Jensen et al., 2001 and Waldron et al., 2002). The Intermountain West region is notorious for micro-climates that can potentially affect water requirements and yields of various pasture mixes. Where specific information does not exist, one should consult with local Extension staff to learn what grass mixes have been successfully grown with available water by other producers in their area.

Soil Properties

Soil serves as the water reservoir for plants to extract their necessary daily ET. However, soils can vary greatly in their ability to hold and supply this water. Soil texture is usually the most important property affecting water holding capacity (Table 2). However, soil structure as affected by tilth and compaction, organic matter, soil salinity, and percent of coarse fragments (gravel and rocks) can change plant available soil moisture significantly in many areas of the West. Irrigators need to adjust table soil moisture values to account for these factors. Soil properties also impact water intake rate (permeability) and soil erosivity. These soil properties affect proper application rates and irrigation system design. Refer to your local NRCS office for soil properties that affect irrigation management.

Table 2. Available water holding capacity (AWC) of selected Western Colorado soils.

Area	Soil Name	Soil Texture	AWC (inches/foot)*
Monte Vista	Gunbarrel	Loamy sand	0.84
Monte Vista	Quamon	Gravelly sandy	1.08
Walden	Walden	Sandy loam	1.32
N. Olathe	Fruitland	Sandy loam	1.39
Monte Vista	San Arcacio	Sandy loam	1.51
Gunnison	Gas	Sandy loam	1.88
Fruita	Fruitland	Sandy clay	1.54
Meeker	Work	Loam	1.80
Yellow Jacket	Wetherill	Loam	2.09
Glenwood Springs	Empedrado	Loam	2.16
Gunnison	Irim	Loam	2.16
Norwood	Callan	Loam	2.26
Fruita/Loma	Sagers	Silty clay loam	2.16
Cortez	Mikett	Clay loam	1.92
Meeker	Zoltay	Clay loam	2.16
Fruita	Turley	Clay loam	2.28
Cortez	Mikim	Clay loam	2.28
Durango	Falfa	Clay loam	2.36

*Available Water Capacity in top foot
**Source: USDA/NRCS Web Soil Survey: http://websoilsurvey.nrcs.usda.gov/app/

In a typical well-drained, non-compacted soil, half of the soil pores are full of water and half are full of air. This is the ideal soil environment for grass root development and growth potential. Therefore, any compaction that occurs - usually as a result of introducing animals into the pasture area too soon after an irrigation event - can upset this important balance and reduce expected yields. Following irrigation, livestock and heavy machinery should be kept off irrigated pasture for at least three days (more for clay soils) to allow excess water to drain below the root zone.

Irrigation Scheduling When and How Much

Cool-season grasses are best adapted to and will maximize their water use efficiency during the spring and fall seasons. Thus, ensuring an adequate water supply during these time periods is wise. Cool-season grasses exhibit drought stress first through slower growth, followed by a dull green color, and finally wilting. However, once visual symptoms of plant water stress appear, yield losses are already occurring before irrigation water can be applied.

Timing irrigation events to meet plant water requirements (ET) without over-application of water while maximizing net returns is a combination of 'art' and 'science'. The 'science' required includes using crop water use information, soil moisture status, and water supply and application information. With this information, an irrigator can develop a water balance or 'checkbook' of soil moisture status to guide decisions on how much water to apply and when. A detailed description of this concept is provided in Chapter 15 Alfalfa Irrigation. However, the water balance must be utilized with other on-the-ground realities such as water availability, precipitation, labor requirements, and harvest and grazing schedules.

Grass water use by month is provided in Tables 1a and 1b. However, daily ET can vary dramatically from day-to-day, so table values are primarily useful for planning purposes. Daily ET values can be obtained from weather station networks or an atmometer (http://www.etgage.com/ articles/csu2.pdf, Fig. 2). In Colorado, a weather station network called CoAgMet (Colorado Agricultural Meteorological Network) provides ET rates at www.coagmet.com. The US Bureau of Reclamation provides ET values in other western states through the AgriMet network: http://www.usbr.gov/pn/agrimet/index.html.

Atmometers can also be used to estimate grass or alfalfa reference ET (see alfalfa section for explanation of "reference ET"). These relatively inexpensive devices are simple to install and maintain, but the ET values do require some adjustment for pasture and grass depending upon the growth stage.

Fig. 2. Atmometer which is used to estimate evapotranspiration (ET) of grass and alfalfa hay crops.

Determining soil moisture status in a field can be accomplished with basic tools, such as a tile spade, or by using more complex tools, such as soil moisture sensors and LCD-display data loggers. All can work equally well when utilized with diligence and some experience. Acquiring the basic tools and skills for gauging soil moisture as part of a short walk across your field is essential for efficient irrigation scheduling and consistently profitable yields (Morris, 2006). First, learning to estimate soil moisture by feel and appearance will help determine the need for irrigation. A useful pocket guide for soil moisture determination, "Estimating Soil Moisture by Feel and Appearance", is available at most USDA/NRCS offices (ftp://ftp-fc.sc.egov.usda.gov/MT/www-/technical/soilmoist.pdf USDA, 1998 - see also Table 3). In general, if a finer textured soil such as a loam or clay loam will form a ribbon when squeezed between your thumb and forefinger, the pasture probably does not

Fig. 3. Soil ribbon.

need additional water (Fig. 3). If it crumbles, an irrigation may be due.

Use of a ball probe can help determine the depth and uniformity of irrigations. The ball on the end of this probe will penetrate wet soil easily but will stop abruptly at a dry soil layer (Fig. 4).

Fig. 4. Soil (bottom) and ball (top) probes are simple, but effective tools for assessing soil moisture.

A primary difference between predominately grass hay and pasture systems and alfalfa is rooting depth. While many grass species can develop rooting systems to five or six feet, the majority of the roots are typically in the top two to three feet of soil. Soaking the soil profile deeper than the root zone results in irrigation inefficiency as water is lost from the root zone through deep percolation. Nutrients such as nitrogen may also be leached out of the root zone when carried by this water.

For most cool-season grasses, allowing 50% depletion of the plant available water in the soil profile prior to irrigation is possible without significant yield-reducing stress. This depletion level is often referred to as the management allowable depletion or MAD. For example, if a grower were managing a field with a Wetherill loam soil, the plant available water holding capacity of this soil is 2.09 inches per foot (Table 2). If this soil received sufficient irrigation or precipitation to fill it to field capacity, which is the maximum amount of plant available water a soil will hold after drainage, then the total amount of plant available water would be approximately 4.18 inches in the top two feet of soil. However, to avoid significant water stress, the irrigator would only want water depletion of 50% or 2.09 inches (1.045 inches per foot) before irrigating. If the average ET rate is 0.20 inches per day, then the next irrigation would need to be completed in roughly 10 days (2.09"/0.20") to avoid water stress. This example assumes that no significant rainfall occurred.

Pasture irrigation management that matches the holding capacity of the soil will not only result in efficient water uptake by a crop, but also help prevent problems that arise from over-irrigation. A rapidly draining, sandier soil such as Quamon (Table 2) will likely shed excess irrigation to the water table, out of reach of the pasture root profile. This may not only contribute to local water quality concerns such as salinity and selenium, but could also leave the irrigator short of water at some point. A loamier clay soil such as Falfa (Table 2) will probably become water-logged with over-irrigation, resulting in soil nutrient loss and eventually crop stress due to "drowning" (i.e. lack of oxygen).

Irrigation Systems

Different irrigation technologies are available to apply water to grass pastures and hay fields. Traditional surface systems such as mountain flood and furrow irrigation are still widely used, with various sprinkler technologies becoming more popular in certain areas. Irrigation technology selection is largely a function of season length, the size and shape of land parcels and the production and profit goals of the producer.

Table 3. Soil moisture descriptions for feel method.

	Soil Texture			
Available Soil Moisture	**Coarse Texture**	**Moderately Coarse Texture**	**Medium Texture**	**Fine Texture**
0-25%	Dry, loose	Dry, forms a very weak ball	Dry. Soil aggregations break away easily, no moisture staining on fingers.	Dry, soil aggregations easily separate
25-50%	Slightly moist, forms a very weak ball with well-defined finger marks	Slightly moist, forms a weak ball with defined finger marks, darkened color	Slightly moist, forms a weak ball with rough surfaces	Slightly moist, forms a weak ball, very few soil aggregations break away
50-75%	Moist, forms a weak ball, darkened color, will not ribbon.	Moist, forms a ball with defined finger marks, will not slick.	Moist, forms a ball, forms a weak ribbon between thumb and forefinger.	Moist, forms a smooth ball with defined finger marks, ribbons between thumb and forefinger.
75-100%	Wet, forms a weak ball, heavy water staining on fingers, will not ribbon.	Wet, forms a ball with wet outline left on hand, makes a weak ribbon.	Wet, forms a ball with well defined finger marks, ribbons.	Wet, forms a ball, ribbons easily between thumb and forefinger.
Field Capacity 100%	Wet, forms a weak ball.	Wet, forms a soft ball, free water appears briefly on soil surface after squeezing or shaking	Wet, forms a soft ball, medium to heavy soil/water coating on fingers	Wet, forms a soft ball, free water appears on soil surface slick and sticky

Larger (>150 acres) parcels on sectioned land with minimal grade are effectively irrigated with pivot sprinklers, while smaller, less uniform areas are better suited to furrows or side-rolls. In mountain environments, the economics of micro-irrigation technologies such as sub-surface drip or micro-sprays are typically not favorable for grass pasture. Local NRCS, Conservation District, and Extension offices can help with technology selection and explaining where cost-share programs are available to help install new irrigation systems.

When using mountain flood or furrow irrigation techniques, the small-scale features of a field have a big influence on the uniformity of water distribution to a pasture crop. Shallow depressions and slight rises of a few inches or more are enough to disrupt water delivery to the feature and surrounding areas. If enough of these features are left unchecked, over time a field can see significant loss of yield and profitability while also giving up valuable irrigation efficiency.

Use of structures from as simple as nylon tarps to more permanent installations such as concrete channels with steel gates can help control irrigation water across mountain meadows and maintain profitable irrigation efficiency (Fig. 5). Your local NRCS, Conservation District, or Extension office can assist with selection and installation of such structures.

Many earthen delivery ditches in mountainous areas are underlain by porous soils that are extremely permeable to water. In

Fig. 5. Example of a headgate used for diverting water in a mountain meadow. Differing numbers of board slats are placed in the slot on the face of the structure to control how much water flows into each of the ditches. (Photo by John Scott)

some cases as little as half the water that was initially diverted may actually reach the meadow being irrigated. Installation of plastic, concrete, or steel ditch linings or some type of delivery pipe can help conserve water and insure that the forage crop receives the amount of water it needs to be productive.

Ditch and canal seepage losses can be reduced, in certain situations, through the application of Linear Anionic Polyacrylamide (LA-PAM) to ditch water. Short term seepage reductions of 28-87% have been measured when LA-PAM was added to ditch water and generally the seepage reduction benefits are maintained for single irrigation season, but do not remain into the next (DRI, 2008). For LA-PAM to be effective and to reduce potential environmental impacts, the receiving water should contain at least 150 ppm (mg L^{-1}) suspended sediment concentration (SSC) for granular LA-PAM and 200 mmp for liquid formulations. A comprehensive review of the LA-PAM effectiveness, application techniques and envi ronmental risk is available at: http://pam.dri.edu/publicdocs.html.

If a producer has access to a measuring device, whether it is a headgate flume or flow meter, the approximate efficiency of the system can be monitored for potential improvements. For instance, a healthy grass hay field in Meeker will typically consume 5 to 6 inches of water during the month of July (Table 4). The amount of water that should be diverted to ensure that the crop is able to absorb 5 to 6 inches depends largely on the effective precipitation, irrigation efficiency and uniformity of the irrigation system for that field. Accounting for rainfall, the crop will need between 4.5 and 5.0 inches of water via irrigation during July to be productive.

A system that distributes water uniformly to the crop at 50% efficiency will require double the water diverted to the field or 9 to 10 inches of water during July to meet the crops water demand; a 75% efficient system under the same conditions will only need to divert half as much more or a total of 6.75 to 7.5 inches of water to satisfy the crops needs.

Table 4. Average seasonal ET for perennial pasture grasses - Meeker, CO (Colorado Irrigation Guide, 1988).

	-- Average Monthly Evapotranspiration (ET) in inches of water --								
	March	April	May	June	July	August	September	October	Total
Grass Pasture ET	0.8	1.33	2.45	3.64	5.34	4.64	2.84	1.11	21.43
Average Effective Precipitation	0.15	0.92	1.12	1.39	0.65	1.09	0.87	0.00	6.19
Required Irrigation	0	0.41	1.33	2.25	4.69	3.55	1.97	1.11	15.31

Note: An inch of water on one acre of land = 1 acre inch = 27,154 gallons. A ditch running at 1 cfs will run enough water for 1 acre inch through it after approximately 1 hour.

To ensure this water is distributed uniformly to the crop again depends on a number of variables, with irrigation scheduling being of particular importance. No matter the irrigation system you are using, the universal symptoms that irrigation water is not distributed uniformly are patches of crop stress or excessive runoff and ponding. Your local Extension or USDA-NRCS office can assist you with determining the efficiency and uniformity of your irrigation system, how improvements can be made to increase yield and profitability and what cost-share programs exist to assist with upgrading your system.

Summary

Irrigation management of grass hay and pastures is an essential component of profit able production. Improved irrigation management includes understanding plant water requirements and soil properties influencing water application timing and amount. Improved irrigation efficiency and uniformity can help stretch limited water supplies and reduce water quality impacts from irrigated systems.

An upgrade to more efficient irrigation technology may pave the way for increased yields and improved stewardship with less labor input. With public programs available that will share the cost of installing new irrigation systems by up to 75% you could be financially benefiting from such a change within a couple of years. Your local Extension, NRCS, or Conservation District office can provide you with more information.

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