Hydrologic Impact of Grazing on Infiltration: A Critical Review

GERALD F. GIFFORD AND RICHARD H. HAWKINS

Watershed Science Unit, College of Natural Resources, Utah State University, Logan, Utah 84322

The hydrologic importance of grazing is receiving increased attention on rangelands in the United States. The literature on this topic is fragmented. This paper explores the available literature for information useful in understanding the hydrologic impacts of grazing intensity as related primarily to infiltration and runoff. Generally, data relative to range condition are not adequate for evaluating hydrologic impacts. Data relating grazing intensity to infiltration rates are available, yet distinct limitations are evident. These limitations are discussed in terms of identifying future research needs. The greatest need appears to be a detailed definition of the long-term effects of grazing (by year and season) on infiltration rates as a function of site, range condition, and grazing intensity. Once obtained, infiltration rates must be coupled with an appropriate method for generating runoff volumes, storm hydrographs, and long-term water yields.

Introduction

Range grazing and its associated environmental effects are rapidly coming under increased public scrutiny. Grazing effects on runoff, erosion, on-site water use, and consequent downstream impacts are especially obvious and of concern. As these processes are affected by grazing, so are nutrient cycles, soil moisture patterns, erosion and sediment yields, downstream water quality, and on-site productivity. Thus an awareness of the grazing impact and an ability to quantitatively describe the impact are essential for the enlightened management of range resources. Current stress on multiple land use and formality of required environmental assessment statements demand a high degree of predictability.

Unfortunately, the literature on hydrologic impacts of grazing is fragmented, and the art/science of rangeland hydrology is only in the developing stages. Thus the purpose of this paper is to explore the available literature for information useful in understanding the hydrologic impacts of grazing as related primarily to infiltration and runoff. It also offers guidelines for future research to the end of enlightened professional multiple-use management.

The Hydrologic Nature of Rangelands

Because of their common environmental inputs and land use, rangelands tend toward a series of common hydrologic characteristics.

In general, rangelands (especially in the western United States) receive low precipitation, maintain sparse cover, are sometimes saline, have variable soils, and undergo a regular if not diffuse harvest. Classical overland flow from rainstorms, found to be infrequent on most forested lands, seems to occur with more regularity on grazing lands. The management of most rangeland is directed toward on-site conservation and use of the usually meager water resource, as contrasted with the espoused goal of water yield improvement from generously watered higher-elevation forest lands.

The Hydrologic Cycle

Examination of the hydrologic cycle suggests that grazing impacts 'might be felt' throughout the surface and near-surface portions, i.e., interception, infiltration, runoff, groundwater recharge, and evapotranspiration. However, only the infiltration process has been studied enough to begin a preliminary analysis of any grazing impact on runoff. There is only limited published material on relating runoff to grazing [*Orr,* 1975; *Rauzi and Hanson,* 1966; *Rich and Reynolds,* 1963; *Leithead,* 1959; *Martin and Rich,* 1948; *Dunford,* 1954; *Gifford et al.,* 1976]. This information is probably best suited for interpreting analyses conducted by using available (though limited) infiltration data. Thus the availability of infiltration data is both important and fortunate, since this process determines, indirectly, the water available for runoff, for recharging soil moisture, for deep seepage and groundwater recharge, and for plant growth.

Grazing Intensity and Range Condition

Grazing activity and its effect are often described by either the grazing 'intensity' or the range 'condition.' Of these two descriptors, intensity (ungrazed, light, moderate, or heavy) is

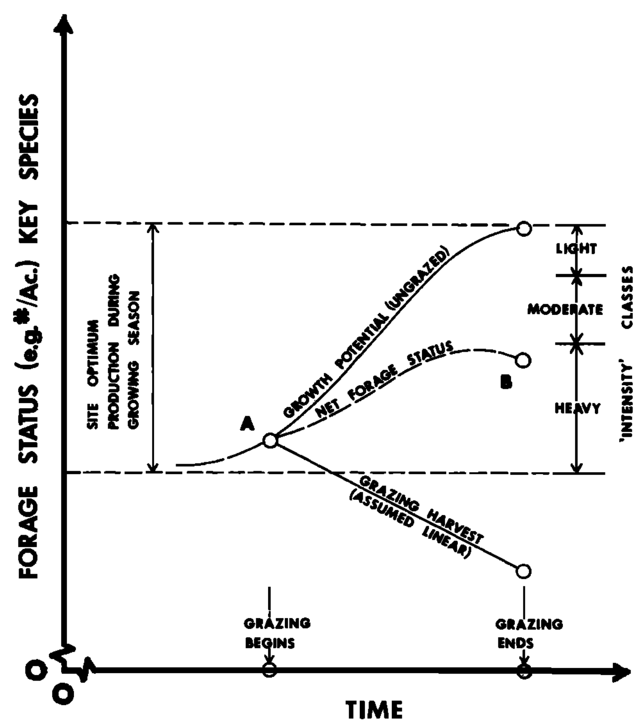

Fig. 1. Diagrammatic representation of the concept of grazing intensity for an example situation. Note that the intensity is defined on the fraction of the key species forage growth consumed over the duration of the activity, regardless of the interim status. The path taken from A to B is unimportant. Boundary locations between the intensity classes are chosen locally, as are the key species.

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TABLE 1. Summary of Grazing Intensity–Infiltration Studies

Site	Equipment	Grazing Intensity: Ungrazed	Light	Moderate	Heavy	Date	Remarks
'Slick' or 'Semislick' soils, Montana [*Branson et al.*, 1962]	tube-type sprinkling infiltrometer*	0.5	0.1		0.2		unfurrowed
		0.1			0.3		unfurrowed dry plots in 1958
		0.3	0.5		0.3		furrowed and seeded in 1948
		2.6	1.5		0.6		furrowed and seeded in 1948
		0.4	0.2		0.6		unfurrowed
			0.3		0.3		unfurrowed moist plots in 1959
		0.4	0.1		0.5		furrowed and seeded in 1948
		1.5	1.5		0.4		furrowed and seeded in 1948
Sandy loam soils, Utah, chained P-J site [*Gifford et al.*, 1976]	Rocky Mountain infiltrometer*	2.3		1.9		June 11, 1974	ungrazed (natural woodland), protected since 1968
		2.6		2.3		June 19, 1974	
		2.9		2.4		June 26, 1974	grazed (chained with windrowing), seeded, grazed since 1974, ungrazed 1968–1973
		2.5		2.6		July 9, 1974	
		2.5		1.6		Aug. 20, 1974	chained and windrowed, seeded in 1964, ungrazed since 1971
		1.3		1.3		July 21, 1974	
		1.5		1.2		Aug. 4, 1974	
		1.4		1.9		June 1975	ungrazed (exclosure on chained with windrowing) seeded site, protected since 1968
		2.0		1.2		Aug. 1975	
		1.4		1.8		June 1976	moderately grazed area since 1974, ungrazed 1968–1973
		1.1		1.0		Sept. 1976	
Loams to clay loams, southwestern Alberta [*Johnston*, 1962]	mobile infiltrometer		2.5(e)	2.0(g)	2.0(g) 1.7(p)		treatment age, 10 years
Loamy fine sand, Oklahoma [*Rhoades et al.*, 1964]	sprinkler infiltrometer	5.3(e)	2.2(g)	1.8(g)	1.6(f)		treatment age, 20 years
	double-ring infiltrometer	12.2(e)	5.8(g)	5.0(g)	3.3(f)		
Silty clay over clay, South Dakota, 2-acre watersheds, rainfall minus runoff [*Sharp et al.*, 1964]			1.2	0.8	0.8		storm of May 30, 1963
			0.4	0.3	0.3	May–July 1963	composite data
Gravelly loam, Arizona [*Tromble et al.*, 1974]	rainfall simulator	1.6			1.2		ungrazed, protected 9 years; heavy grazing utilized 75%
Silty clay loam (loessal material), Kansas [*Knoll and Hopkins*, 1959]	single-ring infiltrometer	1.3		1.0	0.8		ungrazed, protected 13 years
Granitic alluvium, Colorado [*Dortignac and Love*, 1961]	Rocky Mountain infiltrometer*	2.0				1941	grassland, ungrazed beginning 1941
		2.3	0.9	1.2	1.2	1947	
		3.3	1.3	1.4	0.8	1954	
		1.6				1941	ponderosa pine grassland, ungrazed beginning 1941
		2.9	1.5	1.6	1.8	1947	
		2.6	1.8	2.3	0.8	1954	
Silty clay, South Dakota [*Rauzi and Hanson*, 1966]	mobile infiltrometer		3.0	1.7	1.0		dry, treatment age 22 years
			1.3	0.7	0.5		wet, treatment age 22 years
Sandy loam and loams, Colorado [*Rauzi and Smith*, 1973]	mobile infiltrometer*		1.8	2.0	0.8		sandy loam, treatment age 30 years
			1.0	0.9	1.0		sandy loam, treatment age 30 years
			1.8	2.2	1.2		loam
Various soils, North Dakota [*Whitman et al.*, 1964]	probably ring infiltrometer		6.0	3.1			average values over seven major range soil types
Shale-derived soils, Colorado [*Thompson*, 1968]	Rocky Mountain infiltrometer*	0.7		0.8		1953	study began 1953 (first year of protection)
		0.9		1.1		1958	
		0.7		0.8		1963	
Silt loam, Wyoming [*Rauzi*, 1956]	mobile infiltrometer*		1.2		0.9		treatment age 5 years
Silt loams, North Dakota [*Rauzi*, 1963]	mobile infiltrometer	4.3		2.4	1.5		treatment age: heavy 44 years, moderate 46 years, ungrazed 21 years

TABLE 1. (continued)

Site	Equipment	Grazing Intensity				Date	Remarks
		Ungrazed	Light	Moderate	Heavy		
Various soils, Montana [*Reed and Peterson,* 1961]	single-ring infiltrometer	7.3	4.4	4.3	2.8		sandy loam
		4.8			2.2		clay soils, average of all data
		4.3			1.4		clay soils, buffalo grass sod
		4.8			2.5		clay soil, western wheatgrass
		6.7			2.6		silty clay soil, average of all data
		4.5			0.8		silty clay soil, buffalo grass sod
		6.8			3.8		silty clay soil, western wheatgrass
							age of treatment: 7 years ungrazed, all else 14 years
Silty loam, Idaho (G. F. Gifford, unpublished data, 1977)	Rocky Mountain infiltrometer*	1.7		1.4		June 1975	plowed big sagebrush
		1.6		1.4		Aug. 1975	site, ungrazed 1975–1976,
		1.1		0.9		June 1976	moderate since 1970;
		1.3		0.9		Sept. 1976	plowing and seeding in 1968
Clay loams and sandy loams, Pennsylvania [*Alderfer and Robinson,* 1947]	type F rainfall simulator			1.1	0.4		clay loam, blue-grass-clover; heavy, 50–60% cover, moderate, 90% cover
			1.4		0.8		clay loam, bluegrass-clover; heavy, 80–85% cover, light, 100% cover
				0.7	0.8		sandy loam soil
							treatment age for both soils 10 years
Silt loam, Wyoming [*Rauzi,* 1954]	mobile infiltrometer*	1.3	1.7	1.3	1.2		ungrazed for 2 years
		1.2			0.7		ungrazed for 13 years
Fine gravelly loams and silt loams, Wyoming [*Rauzi,* 1955]	mobile infiltrometer*	1.2	1.2	1.3	1.2		fine gravelly loams, ungrazed for 3 years
		1.5	1.5	1.4	1.2		silt loams, ungrazed for 3 years
Silt loam, Louisiana [*Linnartz et al.,* 1966]	double-ring infiltrometer	1.8		1.1	0.7		treatments 10 years old (spring and summer grazing); mostly *Andropogon* spp. on clearcut long-leaf pine forest site; moderate grazing, 47% utilization; heavy, 67% utilization.
Cecil, Madison, and Durham soils (texture not given), South Carolina [*Holtan and Kirkpatrick,* 1950]	type F infiltrometer		1.2	0.7	0.6		probably improved pasture situation, exact conditions not given.

Data are in inches per hour. Symbols in parentheses represent range condition (where given): e, excellent; g, good; f, fair; and p, poor. *Reference provides an estimate of final infiltration rates (f_c) at the end of a specified time period with a sprinkler-type infiltrometer.

the most frequently expressed. It is necessary that their meaning be clear and the usage of terms be understood.

Grazing intensity (Figure 1) may be envisioned as a treatment or rate of utilization (as compared to range condition, which is a status) of range forage. The intensity label carries an intuitive image of rapidity or pressure of use, although this connotation is not entirely correct. Grazing intensity is, in the short run, a description of the fraction utilization of current year forage production from selected key plant species on a range site. Over a longer time perspective it is related to the general health (or vigor) of the same key species. Range condition is an expression of the present state of the plant community on a range site in relation to the potential natural plant community for that site.

INFILTRATION STUDIES

The readily available infiltration studies have been summarized in Tables 1 and 2, the background information on the instrumentation being given in Table 3. A natural breakdown of the infiltration data is on the basis of the management description, i.e., either by grazing intensity (Table 1) or range condition (Table 2). Also, note in Table 3 the variety of both the measurement techniques (sprinkler-type infiltrometer or ring/flooding devices) and the infiltration parameters described (average rates, bulk rates, or 'final' rates). These classifications are important in attempting to extrapolate research results to field application.

For hydrologic analysis purposes the most useful data (of

TABLE 2. Summary of Range Condition–Infiltration Studies

Site	Range Condition				Remarks
	Excellent	Good	Fair	Poor	
Loamy soils, northern Australia (G. F. Gifford, unpublished data, 1977)*		2.3		0.3	Rocky Mountain infiltrometer
Sandy soil, northern Australia (G. F. Gifford, unpublished data, 1977)*		2.6		2.3	Rocky Mountain infiltrometer
Loams to clay loams, southwest Alberta [*Johnston*, 1962]	2.5(l)	2.0(m) 2.0(h)		1.7(h)	treatment age 10 years
Loamy fine sand, Oklahoma [*Rhoades et al.*, 1964]	5.3(u)	2.2(l) 1.8(m)	1.6(h)		sprinkler, treatment age 20 years
	12.2(u)	5.8(l) 5.0(m)	3.3(h)		ring infiltrometer, treatment age 20 years
Gravelly loams, Texas [*Leithead*, 1959]	9.5	5.8	4.3		ring infiltrometer
Fine sand, Nebraska [*Rauzi et al.*, 1968]	4.8	3.2		0.9	mobile infiltrometer
Loam soils, North Dakota (3 sites) [*Rauzi*, 1960]	2.8 3.1 3.2		1.4 0.8 1.2		mobile infiltrometer
Silt loam soils, Montana (4 sites) [*Rauzi*, 1960]		1.4 1.5	0.8 1.0		mobile infiltrometer
Deep fine-textured soils, Texas and Oklahoma (various sites) [*Osborn*, 1952]	5.0 5.1	3.2 3.9 4.2 3.4	 5.0 3.1 4.0 5.8 0.7	2.6 4.3 2.1 1.0 2.5	mobile raindrop applicator
Deep medium-textured soils, Texas and Oklahoma (various sites) [*Osborn*, 1952]		 4.4	2.8 4.0 3.6 2.4 1.2	1.8 3.3 2.5 1.2 1.8	mobile raindrop applicator
Deep coarse-textured soils, Texas and Oklahoma [*Osborn*, 1952]	5.5	2.8	2.0	2.3	mobile raindrop applicator
Shallow soils, Texas and Oklahoma [*Osborn*, 1952]	1.6 3.0	1.4 2.6	1.1 2.0	1.5 1.9	mobile raindrop applicator

Data are in inches per hour. Symbols in parentheses represent grazing intensity (where given): u, ungrazed; l, light; m, moderate; and h, heavy.
*Reference provides an estimate of final infiltration rates (f_c) at the end of a specified time period with a sprinkler-type infiltrometer.

TABLE 3. General Information Regarding Various Infiltrometer Studies Related to Grazing

Reference	Equipment	Age of Treatment	Terminology Associated With Treatments	Form of Data Presentation
Alderfer and Robinson [1947]	type F rainfall simulator	10 years	grazing intensity	rates represent average infiltration rates for 1 hour (soils at field capacity to start)
Branson et al. [1962]	'tube-type' sprinkling infiltrometer[a]	furrowed treatment 10 years old	grazing intensity	rates represent the slope of the curve when a uniform rate of infiltration was reached (soils dry to start)
Dortignac and Love [1961]	Rocky Mountain infiltrometer[b]	see footnotes in table	grazing intensity	rates represent mean f_c infiltration rates (rates during last 20 min of 50-min rainfall application on soils initially at field capacity)
G. F. Gifford (unpublished data, 1977)	Rocky Mountain infiltrometer[b]	ungrazed protected 1975, 1976; grazed since fall of 1970 following plowing and seeding in fall 1968	grazing intensity	rates represent an average for the 5-min period 23–28 min following start of simulated rainfall (soils at field capacity to start)
G. F. Gifford (unpublished data, 1977)	Rocky Mountain infiltrometer[b]	no ages	range condition	rates represent an average for the 5-min period 23–28 min following start of simulated rainfall (soils at field capacity to start)
Gifford et al. [1976]	Rocky Mountain infiltrometer[b]	ungrazed, 8 years; grazed area protected fall 1967 to spring 1974	grazing intensity	rates represent an average for the 5-min period 23–28 min following start of simulated rainfall (soils at field capacity to start)
Johnston [1962]	mobile infiltrometer[c]	treatments 10 years old	grazing intensity and associated range condition	rates represent total water absorbed in first hour (soils dry to start)
Knoll and Hopkins [1959]	single-ring infiltrometer	ungrazed area protected 13 years	grazing intensity	rates represent total water infiltrated after 2 hours (converted to inches per hour)

TABLE 3. (continued)

Reference	Equipment	Age of Treatment	Terminology Associated With Treatments	Form of Data Presentation
Leithead [1959]	infiltration rings[d]	not given	range condition	simply inches per hour, no duration or total volumes of water used indicated (soil probably dry to start)
Osborn [1952]	mobile raindrop applicator[e]	not given	range condition	rates represent water absorbed during 20-min period in which 2 in. of water were applied (adjusted to inches per hour) (plots dry to start)
Rauzi [1954]	mobile infiltrometer[f]	ungrazed for 2 and 13 years	grazing intensity	rates represent average infiltration rates during second 30-min period (adjusted to inches per hour)
Rauzi [1955]	mobile infiltrometer[f]	ungrazed for 3 years	grazing intensity	rates represent average infiltration rates during second 30-min period (adjusted to inches per hour)
Rauzi [1956]	mobile infiltrometer[f]	treatments 5 years old	grazing intensity	rates are for the second 30-min period (adjusted to a 1-hour basis)
Rauzi [1960]	mobile infiltrometer	not given	range condition	rates represent intake rates in inches per hour during second 30 min
Rauzi [1963]	mobile infiltrometer	heavy, 44 years; moderate, 46 years; ungrazed, 21 years	grazing intensity	rates represent average total intake for 1-hour period
Rauzi and Hanson [1966]	mobile infiltrometer[f]	treatments 22 years old	grazing intensity	rates represent total 1-hour amounts (soils run both under dry conditions and at field capacity)
Rauzi et al. [1968]	mobile infiltrometer[f]	not given	range condition	rates represent the second 30-min period (adjusted to a 1-hour basis)
Rauzi and Smith [1973]	mobile infiltrometer[f]	treatments 30 years old	grazing intensity	rates represent infiltration after 60 min of simulated rainfall
Reed and Peterson [1961]	single-ring infiltrometer	ungrazed, 7 years; other, 14 years	grazing intensity	rates represent length of time to absorb 1 in. of water (converted to inches per hour)
Rhoades et al. [1964]	sprinkling infiltrometer[g] and double-ring infiltrometer[h]	treatments 20 years old	grazing intensity and associated range condition	rates represent average water intake rates for 2-hour periods (converted to inches per hour)
Sharp et al [1964]	small watersheds (2 acres each)	treatments 20 years old	grazing intensity	rates are rainfall-runoff for storms of May 30, 1963, and for sum total of all runoff-producing storms, May–July 1963
Thompson [1968]	Rocky Mountain infiltrometer[b]	see footnotes in table	grazing intensity	rates represent infiltration during last 20 min of 50-min infiltrometer run (soils dry to start)
Tromble et al. [1974]	rainfall simulator[i,j]	ungrazed area protected 9 years	ungrazed versus area utilized 75% (therefore deemed heavy)	rates represent average plot infiltration in 60 min (soils dry to start)
Whitman et al. [1964]	not given, probably some sort of ring infiltrometer	not given	grazing intensity	rates are for the second inch of applied water, with values averaged over seven major range soil types
Linnartz et al. [1966]	double-ring infiltrometer[d]	10 years	grazing intensity	rates represent infiltration rates at the end of 70 min
Holtan and Kirkpatrick [1950]	type F infiltrometer[k]	not given	grazing intensity	rates represent infiltration rates at the end of 1 hour

[a] *Adams et al.* [1957].
[b] *Dortignac* [1951].
[c] *Rauzi* [1960].
[d] *Leithead* [1950].
[e] *Osborn* [1951].
[f] *Rauzi* [1963].
[g] *Rhoades* [1961].
[h] *Locke et al.* [1960].
[i] *Morin* [1967].
[j] *Morin et al.* [1970].

those available) are those gathered with a sprinkler-type infiltrometer which gives an estimate of final or constant infiltration rates (f_c) at the end of specified time periods (30, 60, and 120 min). Although other values given are useful in meeting specific study objectives, such as relative treatment comparisons, they do not (at the present time) lend themselves readily to direct application to impact hydrology. However, it is very important to realize that $\int f\,dt$ and f_c provide quite different results for evaluation of grazing, f_c being the less sensitive and perhaps even a poor evaluator of grazing impact in many instances.

Using the above criteria (data gathered with a sprinkling infiltrometer giving some estimate of f_c), many of the data in Tables 1 and 2 are unusable for quantitative hydrologic analyses. However, a number of studies do meet the necessary conditions, and these are indicated in both tables with an asterisk. Most of these are referenced to grazing intensity, this being the grazing identification which will be considered. Infiltration data identified by range conditions are insufficient in number to draw satisfactory relationships. As will be subsequently discussed, this is a recurring shortcoming of studies reviewed.

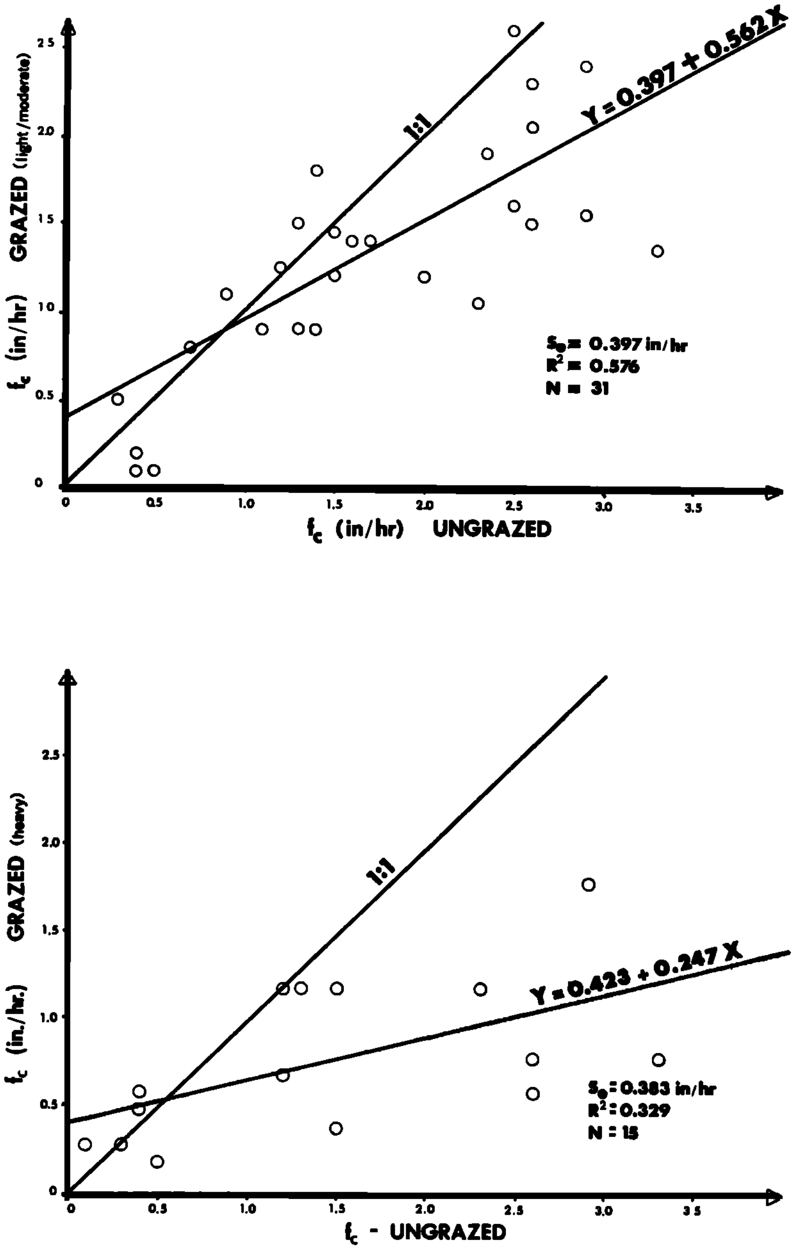

Fig. 2. Relationships between infiltration rates (f_c) on grazed and ungrazed areas.

INTERPRETING GRAZING INFLUENCES

The infiltration data have been plotted by grazing intensity (referenced on an 'ungrazed' intensity), as is shown in Figure 2, and statistically interpreted. The conclusions which may be drawn are summarized below.

1. There is an influence of grazing on infiltration. Note that most of the points fall below the 1:1 line. Ungrazed rates are statistically different from grazed (at any intensity) beyond the 90% level. (See Table 4.)

2. It is difficult to differentiate between the influences of moderate grazing and light grazing. They may be considered (from a statistical sense) to be identical. Figure 2 thus includes data from both moderate and light grazing.

3. There is a distinct impact from heavy grazing which is statistically different from that of light/moderate.

4. There is, as might be expected, a healthy 'noise' level, or standard error, associated with the data. Part of the scatter in Figure 2 can be attributed to variations in interpretation of grazing intensity as given within the literature and also to actual use of pastures within any given intensity class. The latter point may be illustrated by the fact that range production can vary considerably from year to year because of climatic variations (say, by a factor of 5 times or more). Thus a given fraction of use during a low-production year may have a considerably different hydrologic impact than the same fraction of use during a high-production year.

As rough, approximate rules the following definitions might be used for 'average' reactions on more porous soils. Moderate light grazing reduces f_c to about $\frac{3}{4}$ of the ungrazed condition. Heavy grazing reduces f_c to about $\frac{2}{3}$ of the moderate/light condition or $\frac{1}{2}$ (= $\frac{3}{4} \times \frac{2}{3}$) of the ungrazed condition.

APPLICATION AND FUTURE RESEARCH NEEDS

Although the above relationships are both interesting and useful, they could be enhanced by additional detail, replica-

TABLE 4. Results of Paired Data Analysis: Infiltration Rates Associated With Grazing Intensities

Grazing Intensity							
Ungrazed	Light	Light/ Moderate	Moderate	Heavy	*n*	*t*	*P*, %
1.60 (1.00)	1.06 (0.60)				13	2.64	97.9
1.79 (0.73)			1.48 (0.50)		25	2.79	99.0
1.47 (1.01)				0.79 (0.43)	15	3.06	99.1
	1.43 (0.32)		1.56 (0.44)		10	−1.32	78.0
	1.10 (0.61)			0.82 (0.42)	17	2.16	95.3
			1.45 (0.44)	1.12 (0.29)	10	2.32	95.5
1.62 (0.82)		1.30 (0.61)			31	3.21	99.7
		1.13 (0.64)		0.82 (0.42)	17	2.28	96.1

Mean infiltration rates are in inches per hour with the standard deviation in parentheses. Light/moderate values are combined light and moderate data. The t statistic is calculated by a paired difference test. P is the percent probability associated with the t statistic (two-tailed test).

tions, and a wider geographical sampling. As a result, some guidelines may be suggested for future research, and some areas of need outlined. These fall into three general classes, occasionally overlapping: (1) time-related infiltration relations, (2) grazing-related matters, and (3) infiltrometry concerns. These are outlined in the following discussion.

Time Relations

Most of the data listed in Tables 1 and 2 were collected after several years of grazing, with no information on the progress of infiltration rates over time to that point. Was the impact sudden, abrupt, and immediate, or was it gradual? There is little information on this matter either over a span of years or within and throughout a season. For example, if 10 years of heavy grazing had a big impact on infiltration rates, how did this decrease come about? Would the same results have occurred if the area had been grazed at a heavy rate for 1 year? For 2 years? Will the trend continue if heavy grazing is continued for 10 more years, or has the system reached a point of equilibrium? From a hydrologic standpoint, within any given season, will twice the number of animals for half the time create the same impact on infiltration? Is it possible that areas currently grazed lightly and moderately actually recovered from some past grazing abuse, while heavy grazing caused further damage or retained the status quo?

Similarly, the recovery-time relationships are poorly defined. Does the infiltration capacity on a protected site recover from grazing (more specifically, from a given grazing intensity) in 1 year or 100 years? Figures 3–5 show general recovery patterns for grasslands, ponderosa pine grassland, and Mancos shale badlands. The figures indicate that grasslands may still be recovering after 13 years, ponderosa pine grasslands recover after perhaps 6 years, and infiltration rates on sites

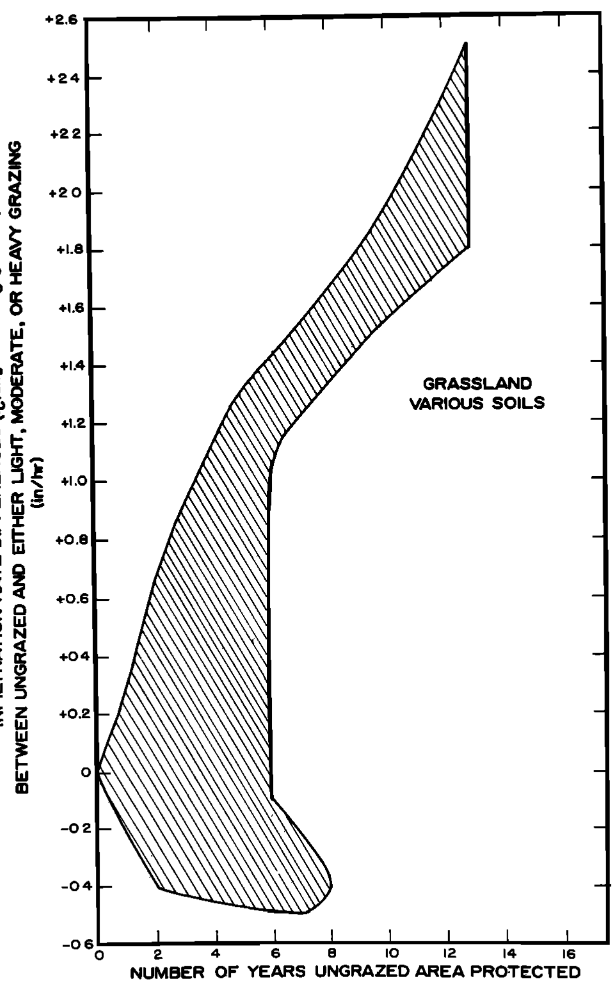

Fig. 3. Impact of protection from grazing on infiltration rates (f_c) for 'grassland' (various soils, various authors).

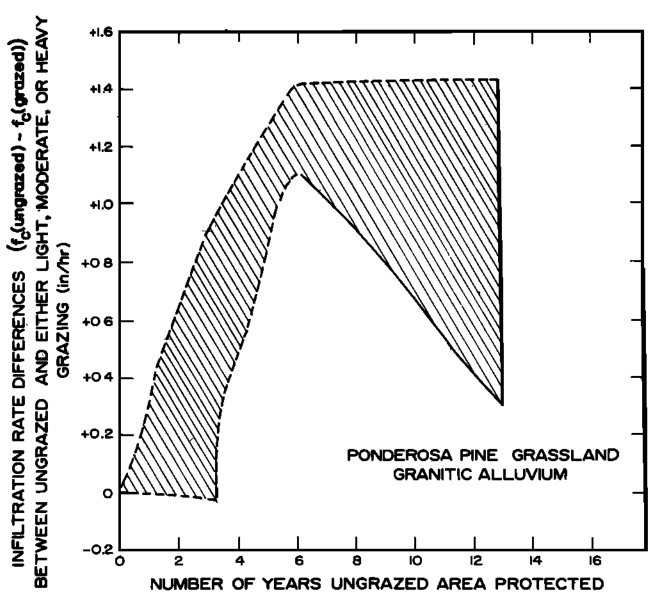

Fig. 4. Impact of protection from grazing on infiltration rates (f_c) for ponderosa pine grassland on granitic alluvium soils. Dashed lines represent uncertain boundaries.

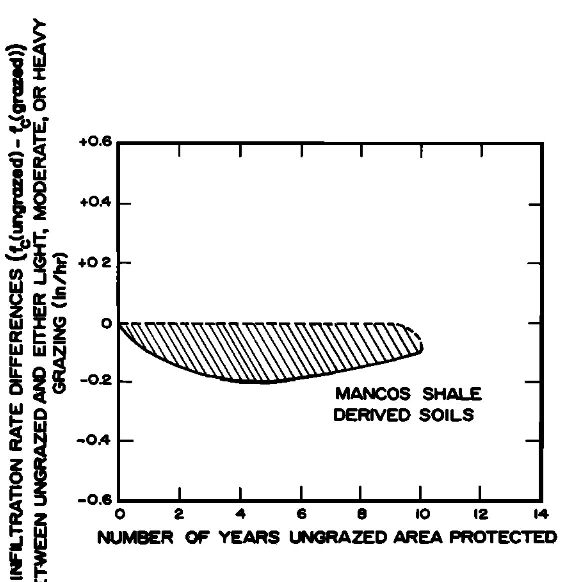

Fig. 5. Impact of protection from grazing on infiltration rates (f_c) for plant communities on Mancos shale derived soils. Dashed line represents uncertain boundary.

derived from Mancos shale are not impacted by grazing. These data are of only limited use, however, since the primary question remains. What are the specific recovery periods for various sites in various range conditions grazed at varying intensities? It seems reasonable to assume that the recovery time and recovery magnitude for excellent condition sites grazed lightly will differ from poor condition sites grazed heavily or that some rest-rotation scheme will recover differently from a system involving continuous grazing.

Recovery-time relationships could be of high importance in timing grazing activities with possible hydrologic reactions. Until these relationships are known, only reasonable alternatives may be assumed and used.

Grazing Influence and Information

The range hydrologist must currently be content with cover (plant, litter, and rock) and herbage use data collected for other purposes and bend the information to fit his needs. Thus the range terminology and associated measurements and concepts used should be fully explained, defined, and detailed in study reports. In dealing with grazing intensity the cover criteria and plant species considered should be included, as well as the duration of use and animal 'loading' (number of animals per unit area). Grazing intensity must be determined through use of utilization and plant physiological data of key plant species on a site and not through simple addition and subtraction of animal numbers. A doubling of animal numbers means nothing from a hydrologic standpoint unless, in this instance, the increase is quantified in terms of grazing intensity based on a study of plant species on site. In addition, the variation of impact with season is unknown. Grazing influences from a plant standpoint differ between winter and summer, and the same may be true hydrologically, especially if snow is present.

The time and space distributions of grazing also confuse hydrologic analyses. The expected animal behavior distribution patterns need to be identified in terms of slope, cover, and distance from water and salt, so that distributions of grazing impact can be estimated and managed.

Infiltrometry Questions

Infiltrometers are one of the few instruments available to make on-site measurements of hydrologic condition. Nonetheless, there are limitations inherent in their usage which should be understood and if possible relaxed for wider application. The emphasis needs to be placed on making actual field infiltration measures and not on measuring factors which may (or may not) be related to infiltration rates.

Although the most useful information has been collected from sprinkling infiltrometers, their use is time consuming. Ring infiltrometers are simpler, quicker, and cheaper, although they provide a less realistic and less areally integrated sample. Thus for the practicing land manager, relationships are needed between results from sprinkling infiltrometers and ring infiltrometers. Such a statement assumes a uniformity between sprinkling infiltrometers and that they are indeed a valid representation of the field rainfall infiltration process. This consideration also needs to be investigated and rectified.

Infiltration information for essentially point samples must be related to an entire watershed. The procedure and rationale for such extension is not at all clear. Thus information is certainly needed on the areal distribution of infiltration rates across watersheds, the variation within small distances, the consequences of using averages, etc. Similarly, a methodology for relating infiltration estimates to watershed runoff needs to be developed. Such technology is currently in its infancy.

SUMMARY

At present, the ability to evaluate the hydrologic impact of grazing is limited. Most of the available literature relates grazing impacts to infiltration rates, yet only a few studies provide a reasonable estimate of constant infiltration rates (f_c) for a given site. Data relative to range condition are not sufficient at this time for evaluating hydrologic impacts. Data relating grazing intensity to infiltration rates are available, yet distinct limitations are evident. These limitations are discussed in terms of identifying future research needs. The greatest need appears to be a detailed definition of the long-term effects of grazing (by year and season) on infiltration rates as a function of site, range condition, and grazing intensity. Once obtained, infiltration rates must be coupled with an appropriate method for generating runoff volumes, storm hydrographs, and long-term water yields.

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