TOPIC 5. PRECIPITATION

Rain and snow are the two forms of precipitation that contribute most to the total precipitation received in the northern regions. While the total amount of precipitation is important, the timing of rainfall and snowfall also has a very direct bearing on primary productivity; late-winter snowfalls that provide soil moisture for germination and adequate rainfall during the first half of the growing season result in higher levels of primary productivity than in areas where soil moisture is inadequate during the first half but plentiful during the second half of the growing season.

The amount of precipitation measured meteorologically is not the same as the effective precipitation ecologically. There are pathways for the dissipation of precipitation that are dependent on the characteristics of the precipitation itself, such as raindrop size, inertia, and the duration of the rainfall period, and on the precipitation history, such as previous rainfall and soil mosture conditions. Heavy rainfall over a short period of time, for example, results in a larger amount of run-off than when the same amount of rain falls over a long period of time. If the soil is saturated, run-off results from even small amounts of precipitation, and floods may occur. Anyone who has lived near a stream is aware of these precipitation intensity and duration effects. Many of these factors are included in a flow sheet in Moen (1973:64).

Solar radiation plays an important role in snowpack characteristics. The rate of snow melt is of primary importance. Snow often melts sooner from areas with favorable solar exposures, such as south-facing slopes and non-forested areas. Solar radiation also conditions the surface of the snowpack for the formation of a nocturnal crust when the snow is exposed to the clear night sky and cools below the freezing point.

The forest canopy with its load of intercepted snow causes changes in the amounts of infrared energy emitted by the canopy. The geometry of a canopy may be very complex, but extensive field measurements in both Minnesota and New York indicate that the amount of radiant energy flux in different habitats under clear skies at night can be predicted with considerable precision, if the atmospheric temperature is known, using equations given in CHAPTER 15. This method was used by Swinbank (1963) also (See Moen and Evans).

Two of the important precipitation characteristics for ecological purposes are considered in this unit: precipitation intensity and the duration of precipitation, both fall and retention, in the soil. It is useful to convert rates to absolute quantities, providing information on the amounts of precipitation physically present to be dissipated, allowing one to develop an accounting procedure while tracing the pathways of precipitation through the hydrologic cycle from the atmosphere to the earth and back to the atmosphere.

LITERATURE CITED

Moen, A. N. and K. E. Evans. 1971. The distribution of energy in relation to snow cover in wildlife habitat. Pages 147-162 In A. O. Haugen (ed.). Proceedings of the Snow and Ice in Relation to Wildlife and Recreation Symposium. Iowa Coop. Wildl. Res. Unit., Iowa St. Univ., Ames. 23 p.

UNIT 5.1: PHYSICAL CHARACTERISTICS

Precipitation elements can be conveniently divided into three basic classes: liquid, freezing, and frozen (Taylor 1954: 159). Rain and snow are the most commonly occurring forms, and these may be further divided into several different types.

Rain and drizzle are liquid forms of precipitation that drop to the ground. Drizzle drops are 0.05 to 0.5 millimeters in diameter and raindrops 0.20 to 7.0 millimeters in diameter (Taylor 1954: 159). Drizzle and rain drops may be supercooled and freeze when striking cold objects and the ground. This is called freezing rain or freezing drizzle, and results in the accumulation of ice on objects such as trees and wires. Hard pellets of ice about the size of raindrops are called sleet. The pellets form when water droplets freeze as they strike ice particles in the atmosphere, and then fall, possibly enlarging as they do.

Ice particles which strike supercooled water particles and enlarge as the freezing water accumulates become hailstones. Hailstones may also alternately fall and rise due to a high level of turbulence in the atmosphere, becoming larger as more ice accumulates, sometimes reaching diameters of 10 cm or more.

Atmospheric moisture which crystallizes results in snowflakes. Flakes are composed of a wide variety of hexagonal crystals. If the crystals combine with additional accumulation of ice crystals, snow pellets, spheres up to 2 mm in diameter, form.

Snow is a dynamic mass that undergoes distinct changes with time. The size distribution of the flakes is a function of atmospheric conditions at the time of flake formation, and affects the density and water content of the new-fallen snow. Accumulated snow ages due to its own mass which results in settling, and to the combining of crystals which results in larger granules.

Some physical properties of snow of importance in wildlife habitat discussed by Moen and Evans (1971) are evaluated further here.

Structure of the Snowpack. New-fallen snow generally has a low density (0.05-0.10 g cm^{-3}) due to the dendritic structure of the crystals. Atmospheric temperature and wind are the two primary factors that alter the density of new-fallen snow. Snow density increases an average of 0.0065 g cm^{-3} for each 1°C increase in surface air temperature at the time of deposition. Reported density of new-fallen snow varies from 0.06 for calm conditions to 0.34 for snow deposited during gale winds. The developed snowpack shows distinct layers characteristic of individual snowstorm deposits and weathering effects (U.S. Army 1956 and Nakaya 1954).

Snow density increases to 0.2-0.4 g cm^{-3} as the age of the snowpack increases. As each new layer of snow is deposited, its upper surface is subjected to weathering effects of radiation, rain, and wind, and interior action of percolating water and diffusing water vapor. The original delicate crystals become coarse grains. These changes affect the thermal properties of the snowpack; the table below gives the values of some of these properties.

Thermal properties of the snowpack in relation to snow density

Density g cm^{-3}	Specific heat cal $cm^{-3}C^{-1}$	Conductivity cal $cm^{-2}C^{-1}$ $cm^{-1}sec^{-1}$
1.000(water)	1.0000	0.00130
0.900(ice)	0.4500	0.00535
0.500	0.2500	0.00205
0.350	0.1755	0.00087
0.250	0.1250	0.00042
0.050	0.0250	0.00002

Nocturnal Snow Crust. The snowpack surface layer cools below 0°C during clear cold nights due to outgoing longwave radiation. Crust formation occurs and is especially pronounced when melting has occurred during the day. The combined effect of air and heat diffusion causes cooling to a depth of approximately 25 cm each clear cold night. There is also a change in the crystalline structure of the surface layer due to this alternate freezing and thawing efect (U.S. Army 1956).

Emissivity and Reflectivity of Snow. The snow surface is composed of small grains of ice, making it extremely rough. The rough snow surface is almost a perfect black body for the absorption and emission of longwave radiation. Since the temperature of snow is limited to a maximum of 0°C, the maximum amount of radiation that may be emitted from the snow surface is 27.45 langleys per hour (a langley is one calorie per square cm per hour) or 274.48 kcal per square meter per hour, calculated from the equation below.

$$QREE = (IREM)(SBCO)(ABTE^4)$$

where QREE = Infrared radiation flux in kcal per square meter per hour,
IREM = Infrared emissivity (Maximum of 1.0),
SBCO = 4.93×10^{-8} kcal per square meter per hour, and
ABTE = 273.16 + Celsius temperature

Snow is a good reflector of radiant energy in the visible portion of the electromagnetic spectrum. The reflectivity (albedo) is dependent upon the age of the snow surface. During the accumulation season, the albedo may decrease from 80% to 60% in 15 days, and during the melt season the albedo may decrease from 80% to 45% in the same time period (U.S. Army 1956).

Conductivity. Factors affecting the thermal conductivity of snow are: (1) the structural and crystalline character of the snowpack, (2) the degree of compaction, (3) the extent of ice planes, (4) the wetness, and (5) the temperature of the snow. Experimental work shows that the thermal properties of snow (specific heat, conductivity, and diffusivity) can be predicted from snow density measurements (see the Table on page 58).

Heat transfer in a natural snowpack is complicated by the simultaneous occurrence of many different heat exchange processes. The water vapor condenses and yields its heat of vaporization (0.600 kcal g^{-1}) upon reaching a cold surface. Rain or melt water freezes within the sub-freezing layers and adds the heat of fusion (0.08 kcal per gram). These two processes tend to change and influence the conductivity and diffusivity of the snow throughout the pack and influence the heat transfer rates (U.S. Army 1956).

Temperature gradients in the snowpack are more pronounced in the winter than in the spring. When the snowpack reaches an isothermal condition at 0°C, the heat energy is dissipated in melting the snow. The cooling effect of nocturnal radiation is an effective factor in determining the temperature gradients that develop within the top 5 to 40 cm of the snowpack.

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Taylor, G. F. 1954. Elementary Meteorology. Prentice-Hall, Inc., New York. 364 p.

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REFERENCES, UNIT 5.1

PHYSICAL CHARACTERISTICS

BOOKS

TYPE	PUBL	CITY	PAGE	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
aubo	haup	cama	510	----	snow cryst: nat and artifi	nayaka,u	1954

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR

UNIT 5.2: RAINFALL AND SNOWFALL INTENSITIES AND ACCUMULATION

Precipitation intensity is the amount of precipitation over a stated time period. Suppose one wishes to express the amount of rainfall, in cm, over one-hour time periods. The precipitation in cm per hour (PCMH) may be used to calculate the total amount of precipitation in cubic **meter per** hectare in one hour formula:

$$TPMH = PCMH/(1 \times 10^6)$$

where TPMH = total precipitation in cubic meters per hectare, and
PCMH = precipitation in cm pev hour and
1×10^6 = the number of square meters in a hectare.

Total precipitation on a given land area over a specified time may be determined by multiplying PCMH from the previous UNIT by the duration of precipitation in hours (DUPH). The formula for calculating the total precipitation, in cubic meters per hectare, that reaches the soil surface during a given rainfall event is:

$$TPMH = [(PCMH)(DUPH)]/1 \times 10^6$$

The mass of precipitation may be calculated by multiplying the volume by the density per unit volume. In metric units, one cubic centimeter of water weighs one gram, so 1000 cc weighs 1 kg, and a cubic meter weighs 1000 kg. WORKSHEET calculations illustrate that the mass of water that falls on a hectare even in an hour of light rain is very large indeed!

Rainfall through the year often results in patterns; some months are usually drier than others. The precipitation pattern over the annual cycle may be somewhat symmetrical, suitable for expression as a numerical as a function of time, or it may be variable. Since local precipitation patterns are much less predictable than other weather patterns, such as solar radiation and air temperature, a general formula cannot be given here.

The interception of falling rain and snow is an important factor when predicting accumulation on the ground. The amount of interception varies greatly depending on the type and density of the vegetation cover, and the magnitude, intensity, and frequency of storms. High winds reduce the amount intercepted, and intense solar radiation reduces the amount of snow trapped in the canopy. A moderately dense coniferous forest in an area with annual precipitation of 30-50 inches (76-127 cm) may intercept 15-30% of the total winter precipitation. A formula was developed for estimating the amount of interception in a northwestern (United States) coniferous tree stand as follows (U.S. Army 1956):

$$\text{Percent interception} = 0.36 \times \text{canopy cover (\%)}.$$

LITERATURE CITED

United States Army. 1956. Snow Hydrology. N. Pacific Div., Corps of Engr., U.S. Army, Portland, OR. 437 p.

REFERENCES, UNIT 5.2

RAINFALL AND SNOWFALL INTENSITIES AND ACCUMULATION

BOOKS

TYPE	PUBL	CITY	PAGE	KEY WORDS----------------------	AUTHORS/EDITORS--	YEAR
edbo	pepr	oxen	813	forest hydrology, intern suympo	sopper,we,ed; lul	1967

SERIALS

CODEN	VO-NU	BEPA	ENPA	KEY WORDS----------------------	AUTHORS----------	YEAR
AFJZA	143-6	117	121	throughfll,stmflw,intrcpt,d-fir	heuveldop,j; mit/	1972
BAMIA	42--2	119	121	percipitable water nomogram	peterson,kr	1961
BTBCA	88--1	21	29	forest ecology of ice storms	Lemon,pc	1961
CJFRA	1---1	20	31	eval summr rnfall, aspn commun	clements,jr	1971
CJFRA	4---1	91	96	snow damage, yng red pine stnds	neary,dg; day,mw/	1974
FRSTA	27--1	41	53	compar rainfll, diffrnt wdlands	ovington,jd	1954
JAMOA	1---2	203	207	precipita meas relate to expos	brown,mj; peck,el	1962
JAMOA	1---3	343	347	terr influence prec, interm we	williams,p; peck,	1962
JFUSA	49-12	869	871	snow accum, reten, pond pine ln	haupt,hf	1951
JFUSA	64--1	16	18	snow damage, yng northrn hrdwds	blum,bm	1966
JGREA	65--3	959	982	rainfall, tropic, non-trop sto	hershfield,dm; wi	1960
JGREA	65--9	2877	2881	evaporati loss small or rain g	gill,he	1960
JGREA	65-12	4017	4024	reliabil hourly precipita data	court,a	1960
JGREA	66--6	1823	1831	area-depth rainfall formula	court,a	1961
JGREA	68-16	4723	4729	comparis perfect 5 raingag ins	allis,ja; harris/	1963
JGREA	68-16	4763	4767	accur estimati watersh mean ra	mcguinness,jl	1963
JSWCA	23--5	181	184	intrcpt-trnspr rel,w spr,w pine	nicolson,ja; tho/	1968
JYCEA	87HY5	99	116	estimation prob maximum precip	hershfield,dm	1961
MWREA	80--8	129	133	interpola missin precipit reco	paulhus,jlh; kohl	1952
SIFEA	119-3	1	37	distr rainfall diff for stands	paivanen,j	1966

CODEN	VO-NU	BEPA	ENPA	KEY WORDS---------------------	AUTHORS----------	YEAR
TAGUA	35--2	203	206	precipita, alaska, greater tha	black,rf	1954
TAGUA	35--2	206	207	discussion of pages 203-206	wilson,wt	1954
TAGUA	36--4	689	694	standard, small or rain gauge	huff,fa	1955
XARRA	92---	1	4	snow damag, pole stand, wh pine	watt,rf	1951
XPNWA	40---	1	10	snow damag conif seedlng, sapln	williams,cb,jr	1966

OTHER PUBLICATIONS

Bruce, J. P. 1968. Atlas of rainfall intensity-duration frequency data for Canada. Climatological Studies No. 8, Toronto.

Fenton, R. H. 1959. Heavy snowfalls damage Virginia pine. Sta. Pap. Ntheast. For. Exp. Sta., No. 127. 7p.

Godman, R. M., and R. L. Olmstead. 1962. Snow damage is correlated with stand density in recently thinned Jack pine plantations. Tech. Note Lake St. For Exp. Sta., No. 625. 2 p.

Nicholson,J. W. 1930. Forests and rainfall. Empire Forestry Jour. 9(2):204-212

U. S. Department of Commerce Weather Bureau. 1946. Manual for Depth-Area-Duration Analysis of Storm Precipitation. Washington, D. C. 72 p.

U. S. Department of Commerce Weather Bureau. 1951. Tables of Precipitable Water. Technical Paper No. 14. Washington, D. C.

U. S. Weather Bureau. 1961. Rainfall-frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years. Technical Paper No. 40.

CHAPTER 14, WORKSHEET 5.2a

The mass of water falling as precipitation

Rainfall is so often measured in inches or centimeters that we seldom think of the mass of water falling during a rainy period. Using the metric system, calculate the mass of rain falling over 1 hectare given different rates of fall in cm per hour.

Rate (cm/hr)	Mass (kg/ha)
______	______
______	______
______	______
______	______
______	______

Convert these to inches per hour and lbs per acre. One inch = 2.54 cm, one pound = 0.4536 kg, and one acre = 2.47 hectares.

Rate (inches/hr)	Mass (pounds/acre)
______	______
______	______
______	______
______	______
______	______

CHAPTER 14, WORKSHEET 5.2b

Cumulative precipitation

Precipitation records are often given as "cumulative amount for the year." Check local weather records and record the cumulative precipitation for the 12 months in the blanks below. Then, list the monthly totals. If there is a pattern, derive an equation. If not, divide the months into 52 7-day periods of JDAY's. Either the equation or the 7-day periods will be used in compiling weather profiles in CHAPTER 17. Another table is found on the next page.

	J	F	M	A	M	J	J	A	S	O	N	D
Cumulative totals:	____	____	____	____	____	____	____	____	____	____	____	____
Monthly totals:	____	____	____	____	____	____	____	____	____	____	____	____

Equation?

7-Day expected totals:

1 _____	92 _____	183 _____	274 _____	365 _____
8 _____	99 _____	190 _____	281 _____	
15 _____	106 _____	197 _____	288 _____	
22 _____	113 _____	204 _____	295 _____	
29 _____	120 _____	211 _____	302 _____	
36 _____	127 _____	218 _____	309 _____	
43 _____	134 _____	225 _____	316 _____	
50 _____	141 _____	232 _____	323 _____	
57 _____	148 _____	239 _____	330 _____	
64 _____	155 _____	246 _____	337 _____	
71 _____	162 _____	253 _____	344 _____	
78 _____	169 _____	260 _____	351 _____	
85 _____	176 _____	267 _____	358 _____	

	J	F	M	A	M	J	J	A	S	O	N	D
Cumulative totals:	____	____	____	____	____	____	____	____	____	____	____	____
Monthly totals:	____	____	____	____	____	____	____	____	____	____	____	____

Equation?

7-Day expected totals:

1 ____	92 ____	183 ____	274 ____	365 ____
8 ____	99 ____	190 ____	281 ____	
15 ____	106 ____	197 ____	288 ____	
22 ____	113 ____	204 ____	295 ____	
29 ____	120 ____	211 ____	302 ____	
36 ____	127 ____	218 ____	309 ____	
43 ____	134 ____	225 ____	316 ____	
50 ____	141 ____	232 ____	323 ____	
57 ____	148 ____	239 ____	330 ____	
64 ____	155 ____	246 ____	337 ____	
71 ____	162 ____	253 ____	344 ____	
78 ____	169 ____	260 ____	351 ____	
85 ____	176 ____	267 ____	358 ____	

CHAPTER 14 - WORKSHEET 5.2c

Snow depths in different cover types

Snow interception, wind effects, and radiant energy distribution affect snow depths in different cover types. Measure depths at 10 or more locations in different cover types and evaluate the results. Statistical tests of differences between means are appropriate for such data.

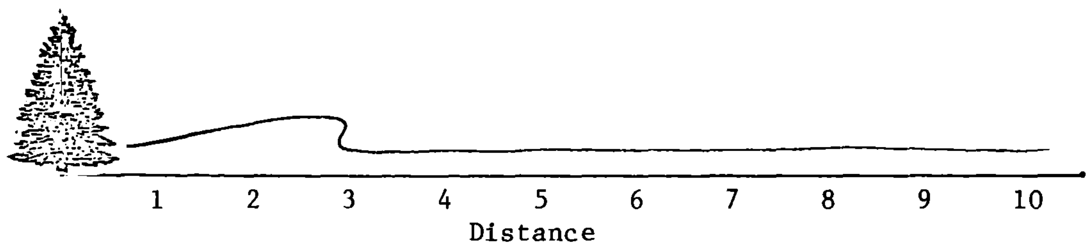
Cover type	1	2	3	4	5	6	7	8	9	10	$\bar{x}$	SD

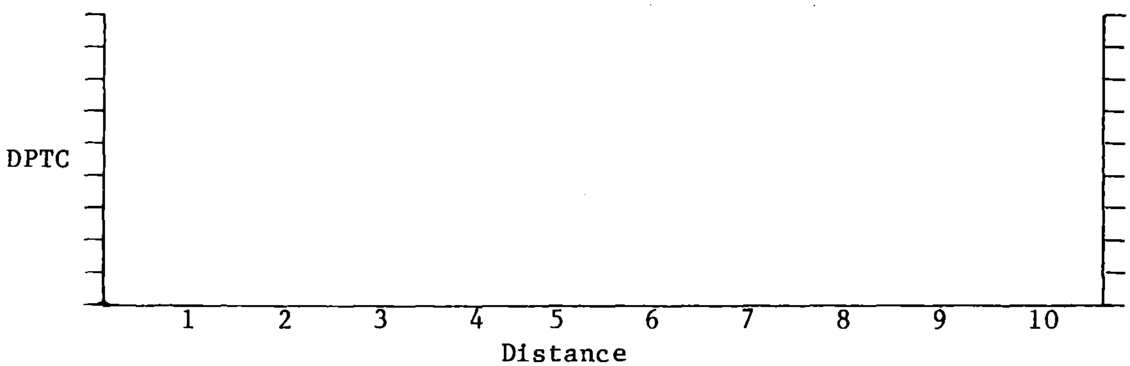
Cover type	1	2	3	4	5	6	7	8	9	10	$\bar{x}$	SD

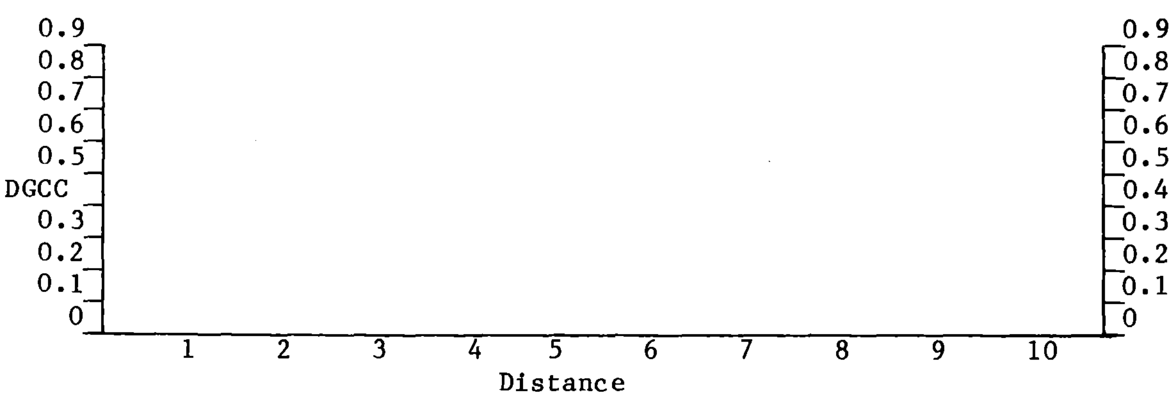
CHAPTER 14, WORKSHEET 5.2d

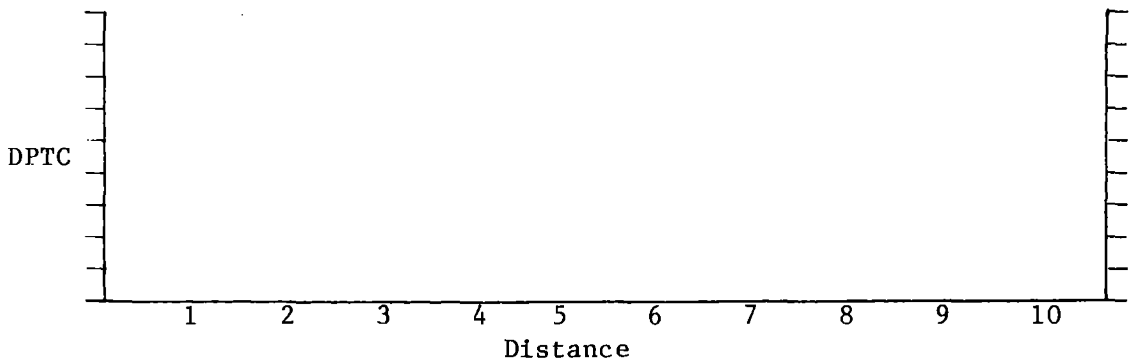
Snow drift characteristics

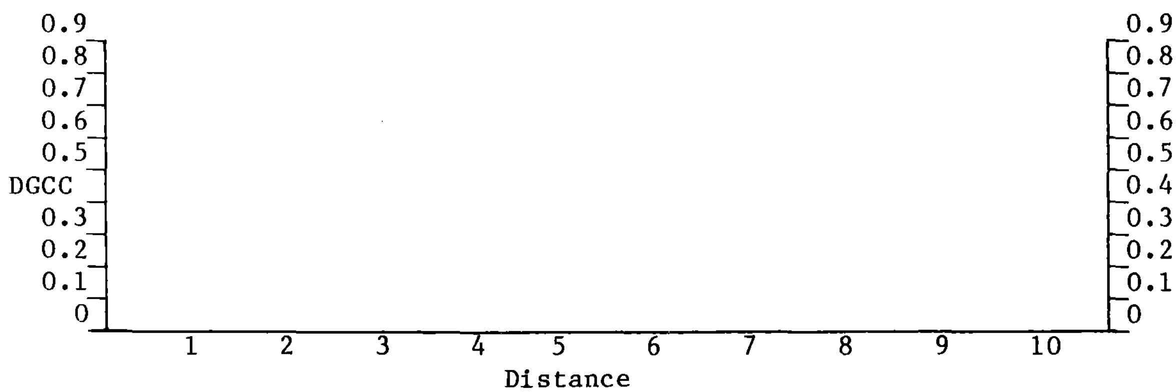
Snow drift geometries depend on wind and habitat characteristics. Measure the depths and densities of snow drifts in a systematic way as illustrated below. DPTC = depth in cm and DGCC = density in grams per cubic centimeter.








DPTC
1
2
3
4
5
6
7
8
9
10
Distance


0.9
0.8
0.7
0.6
0.5
DGCC
0.3
0.2
0.1
0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8
9
10
Distance

The rates at which rainfall runs off the soil surface, is absorbed by the soil, and percolates away are used to determine the amounts present in the soil at the ends of specified time periods.

The amount of water that enters the soil is equal to the amount of rainfall minus the runoff. Runoff may be determined by subtracting the amount absorbed by the soil from the amount of rainfall. The maximum amount that can be absorbed by the soil may be expressed by an absorption coefficient (ABCO). Its numerical value is dependent on soil characteristics that determine water-holding cpacity. A simple formula for determining runoff is:

$$ROMH = (TPMH)(1 - ABCO)$$

where ROMH = runoff in cubic meters per hectare,
TPMH = total precipitation in cubic meters per hectare, and
ABCO = absorption coefficient of the soil.

The amount of water in cubic meters per hectare (WAMH) that enters the soil may be expressed as:

$$WAMH = TPMH - [(TPMH)(1 - ABCO)] = [(PICH)(DUPH)]/(1 \times 10^6) - (PICH)(DUPH)(1-ABCO)$$

where PICH = precipitation in cm, and
DUPH = duration of precipitation in hours.

The formula for WAMH may be simplified by multiplying the total precipitation by ABCO:

$$(WAMH)(TPMH)(ABCO) = [(PICH)(DUPH)]/1 \times 10^6 (ABCO)$$

Calculations with the formulas above are easy to complete on a hand calculator. The amounts of precipitation reaching the earth's surface, run-off and water absorbed may also be estimated with nomograms. The grid in WORKSHEET 5.3a may be used to construct nomograms for the calculated values.

REFERENCES, UNIT 5.3

RAINFALL DISPERSION

BOOKS

TYPE	PUBL	CITY	PAGE	KEY WORDS---------------------	AUTHORS/EDITORS--	YEAR
aubo	copr	nyny	137	landslide and related phenomen	sharpe,cfs	1938
aubo	jwed	aami	763	flow homog fluid porous materi	muskat,m	1946
aubo	jwis	nyny	498	soil physics	baver,ld	1948
aubo	mhbc	nyny	394	forest influences	kittredge,j	1948
aubo	mhbc	nyny	689	applied hydrology	linsley,rk; kohl/	1949
edbo	dove	nyny	712	p. 561-571, in: hydrology	meinzer,oe, ed	1949
edbo	jwis	nyny	376	ch. 5, flow of groundwater	rouse,h,ed	1949
aubo	ropr	nyny	412	vegeta and watershed management	colman,ea	1953
aubo	cnha	loen	492	vol. 1, irr, hydraul desig	leliavsky,s	1955
aubo	prha	ecnj	356	engineering hydrology	butler,ss	1957
edbo	amsa	mawi	620	part I, drain agriculturl lands	luthin,jn,ed	1957
aubo	mhbc	nyny	340	hydrology for engineers	linsley,rk; kohl/	1958
aubo	jwis	nyny	408	hydrology	wisler,co; brater	1959
aubo	mhbc	nyny	...	handbook of applied hydrology	chow,vt	1964
edbo	pepr	oxen	813	p. 137-161, sym for hydrology	sopper,w; lull,h,	1967
edbo	pepr	oxen	813	p. 261-274, sym for hydrology	sopper,w; lull,h,	1967
edbo	pepr	oxen	813	p. 275-290, sym for hydrology	sopper,w; lull,h,	1967
edbo	pepr	oxen	813	p. 335-343, sym for hydrology	sopper,w; lull,h,	1967
edbo	pepr	oxen	813	p. 599-611, sym for hydrology	sopper,w; lull,h,	1967
edbo	pepr	oxen	813	p. 701-702, sym for hydrology	sopper,w; lull,h,	1967

SERIALS

CODEN	VO-NU	BEPA	ENPA	KEY WORDS---------------------	AUTHORS----------	YEAR
AGJOA	54--5	385	390	availabili soil water to plant	denmead,ot; shaw,r	1962
BTBCA	82--3	155	162	moss cover, rainfall intercept	moul,et; buell,mf	1955
BUGMA	56---	275	370	erosional developm of streams	horton,re	1945
CIEGA	10--3	165	166	hydraulic of surface runoff	sherman,lk	1940
CIEGA	12-10	571	572	flood hydrographs	commons,gj	1942
CJSSA	41--1	115	124	depth freezing spring runoff	willis,wo; carlso/	1961
CWBSA	50---	1	91	relativ between water and soil	marshall,tj	1959
CWBSA	53---	1	124	vegetation and hydrology	penman,hl	1963
ECMOA	10--2	243	277	intercept rainfa by prarie gra	clark, or	1940
ENREA	108--	501	502	streamflow from rain, unit-gr	sherman,lk	1932

CODEN	VO-NU	BEPA	ENPA	KEY WORDS----------------------	AUTHORS----------	YEAR
FOSCA	6---1	2	10	distribut of rainfal under for	voigt,gk	1960
FOSCA	9---4	413	422	evaluatio eff top, soil wat ba	nash,aj	1963
FOSCA	9---4	423	429	net precipita under doug-fir f	rothacher,j	1963
HILGA	12--6	383	426	water condition fr shallow tab	moore,re	1939
HYSBA	6---3	5	17	increased water yield, for cut	hewlett,jd; hibber	1961
HYSBA	11--2	14	19	water repel soil wildlfire	debano,lf; krammes	1966
JAGRA	34--9	797	823	runoff from agricultural areas	ramser,ce	1927
JFUSA	42-12	890	898	components rainfall intercept	grah,rf; wilson,cc	1944
JFUSA	60--7	485	486	range soil moisture, so appal	helvey,jd; hewlett	1962
JFUSA	63-10	756	760	summar water use asp, spr, gra	brown,he; thompson	1965
JGREA	65--2	655	661	translocation moist unsat soil	nixon,pr; lawless,	1960
JGREA	65--8	2389	2394	intercept loss from grass	mcmillan,wd; burgy	1960
JGREA	65-11	3850	3851	interception loss equation	merriam, ra	1960
JGREA	66--6	1994	1994	discuss of r. a. merriam pape	kohler,ma	1961
JGREA	68--4	1081	1087	moisture, energy, slope, drain	hewlett,jd; hibber	1963
JRCEA	84IR1	1507	1-26	compre consumptive use water	criddle,wd	1958
JSWCA	18--6	231	234	precipitati intercep by plants	goodell,bc	1963
MWREA	47--9	603	623	rainfall interception	horton,re	1919
MWREA	87--2	101	106	modulated soil moisture budge	holmes,rm; roberts	1959
MWREA	90--4	165	166	theory of "equival slope"	lee,r	1962
NASRA	544--	20	47	landslide type, processes	varnes,dj	1958
PAEBA	B78--	1	152	bibliogr method det soil mois	shaw,md; arbele,wc	1959
PHDSA	2----	184	196	estimate soil mois, evapo data	holmes,rm	1961
SCIEA	13539	522	523	imped water movement, soil, pl	gardner,wr; ehlig,	1962
SOSCA	11--3	215	232	movement of soil moisture	gardner,w; widstoe	1921
SOSCA	67---	29	40	diffi theory, laws captur flow	kirkham,d; feng,cl	1949
SOSCA	67---	403	409	soil character, eval permeabil	oneal,am	1949
SOSCA	68---	359	370	press pot of water moving	marshall,tj; stirk	1949
SOSCA	83--5	345	357	infil equation and solution	philip,jr	1957
SOSCA	85---	185	189	per measure soil crust, rain	mcintyre,ds	1958
SOSCA	97--5	307	311	measure hydro cond unsat porou	youngs,eg	1964
SSSAA	3----	340	349	runoff plat experiment, erosio	horton,re	1938
SSSAA	5----	399	417	physical inter of infil capaci	horton,re	1940
SSSAA	7----	95	104	infil frost penetrat, mic-clim	post,fa; dreibelbi	1942
SSSAA	8----	116	122	condition, entry water, s	bodman,gb; colman,	1943
SSSAA	11---	21	26	suggested lab stand subsoil pe	smith,rm; browning	1946
SSSAA	16--1	33	38	hydraulic gradient, infiltrati	miller,rd; richard	1952
SSSAA	16--1	62	65	root channel, root, forest	gaiser,rn	1952

CODEN	VO-NU	BEPA	ENPA	KEY WORDS----------------------	AUTHORS----------	YEAR
SSSAA	17--3	195	201	water entry, movemen soil core	taylor,sa; heuser,	1953
SSSAA	17--3	206	209	capillary conductive values	richards,sj; weeks	1953
SSSAA	20--2	284	288	soil moisture availa, power re	taylor,sa; haddock	1956
SSSAA	20--3	310	314	physical proc dete water loss	richards,la; gard/	1956
SSSAA	20--4	458	462	measureme soil moist diffusivi	bruce,rr; klute,a	1956
SSSAA	22--2	106	110	sim root distribution water re	vaquez, r; taylor,	1958
SSSAA	26...	107	111	different analy, unsat flow pr	neilson,dr; bigga/	1962
SSSAA	26...	530	534	number soluti, moist flow equa	hanks,rj; bowers,s	1962
SSSAA	27--5	590	592	soil-erodability evaluation	olson,tc; wischmei	1963
SSSAA	29--4	472	475	tree space, under vegetati wat	barrett,jw; youngb	1965
SSSCA	7----	665	670	infiltrati meltwater, frozen s	kuznik,ia; bezmeno	1963
TACEA	79---	1056	1155	compositi runoff, rainf, other	meyer,af	1915
TACEA	101--	140	206	rainfall, runoff, urban areas	horner,ww; flynt,f	1936
TAGUA	14---	446	460	infiltrati in the hydrol cycle	horton,re	1933
TAGUA	18--2	361	368	rate infiltration water, irri	lewis,mr	1937
TAGUA	20--4	721	725	structural disch-reces curves	barnes,bs	1939
TAGUA	21---	558	570	graphical, sprink-pl hydrology	sharp,al; holtan,h	1940
TAGUA	23--2	578	593	pt II, analyses hydro contol-p	sharp,al; holtan,h	1942
TAGUA	27--6	863	870	effect freezin on mois, evapor	anderson,hw	1946
TAGUA	39--2	285	291	rainfall energy and soil loss	wischmeier,wh; smi	1958
TFSOA	17--2	228	243	system soil-soil moisture	keen,ba	1922
UUARA	15---	1	28	evaporati drying of porous med	wiegand,cl; taylor	1961
WRERA	1---2	193	206	canopy, litter intercepti, rai	helvey,jd; patric,	1965
WRERA	1---2	283	286	soil wettability, management	krammes,js; debano	1965
WRERA	3---3	891	895	linear analyses of hydrograph	mitchell,wd	1967
WRERA	6....	465	477	runoff from watershed model	black,pe	1970
WRERA	6....	478	490	investigat runoff prod, perme	dunne,t; black,rd	1970
WRERA	6....	1327	1334	theoret estima vs for water yi	lee,r	1970
XAARA	41-51	1	25	infiltrati est in watersh engi	holtan,hn	1961
XAFNA	159--	1	16	intercept precipit by nor hard	leonard,re	1961
XAGCA	910--	1	64	plant-soil-water relation, man	lassen,l; lull,hw/	1952
XAMPA	768--	1	33	soil compaction, forest, ran	lull,hw	1959
XANEA	1----	1	79	effect streamflow, 4 for pra	reinhart,kg; esch/	1963
XAPWA	43---	1	12	soil wettability, wetting agen	debano,lf; osborn/	1967
XASEA	132--	----	----	soil moisture, base flow, stee	hewlett,jd	1961
XFNNA	41---	1	4	sustained winter streamflow	federer,ca	1966

CODEN	VO-NU	BEPA	ENPA	KEY WORDS--------------------	AUTHORS-----------	YEAR
XIPPA	252..	1	57	hydraul geometry of stream cha	leopold,lb; maddoc	1953
XIPPA	269..	----	----	water-loss investigations	us geological surv	1954
XIWSA	968C.	125	155	topograp chara drainage basins	langbein,wb et al.	1947
YAXAA	1955B	346	358	water budget, use in irrigatio	thornthwaite,cw; m	1955

OTHER PUBLICATIONS

Broadfoot, W. H. and H. D. Burke. 1958. Soil moisture constants and their variation. U. S. Forest Service Southern Forest Experiment Station, Occasional Paper No. 166.

Cooper, C. F. 1960. Ecological classification in watershed management. Proceedings of the Fifth World Forestry Congress. Seattle, Washington. Vol. 3: 1731-1734.

Crawford, N. G. and R. K. Linsley. 1965. A conceptual model of the hydrologic cycle. Symposium of Surface Waters International Association of Scientific Hydrology. Publication No. 63: 573-587.

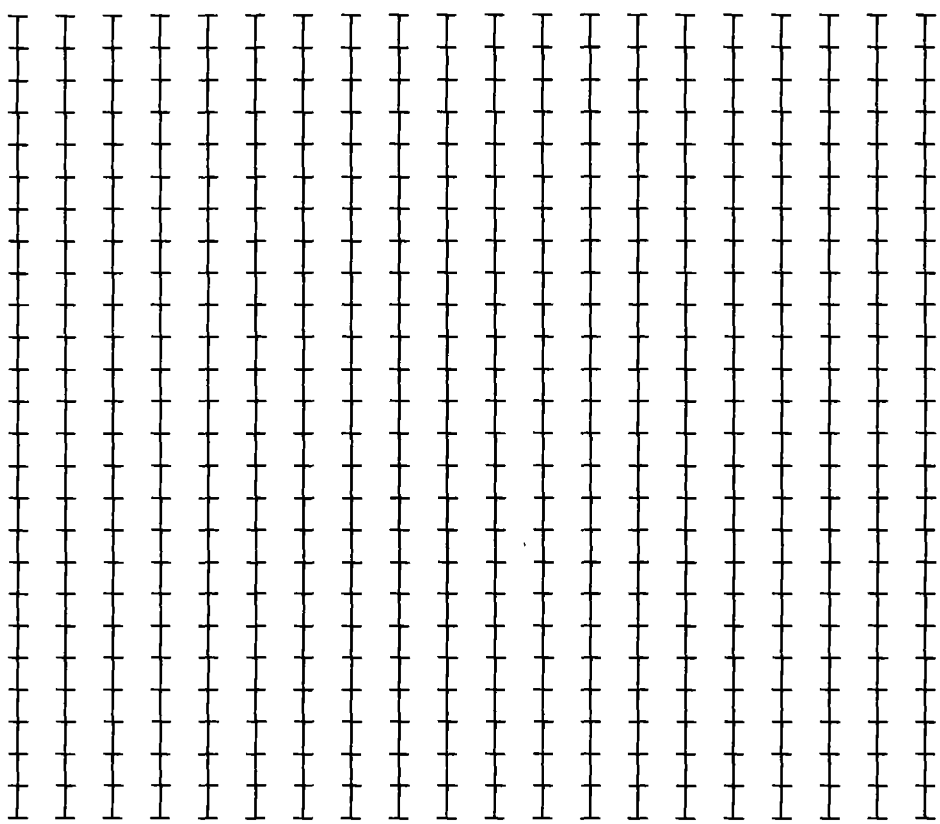
Koshi, P. T. 1959. Soil moisture trends under varying densities of oak overstory. Occasonal Paper No. 167. U. S. Forest Service, Southern Forest Experiment Station, New Orleans, La.

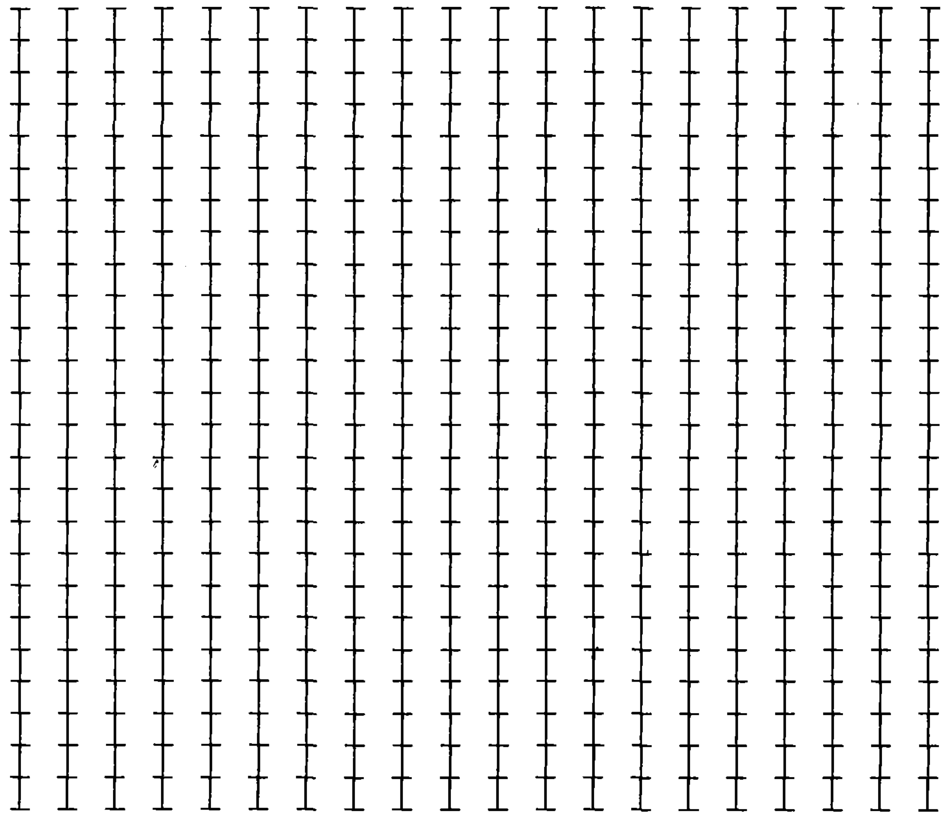
Megahan, W. F. and D. R. Satterlund. 1961. Winter infiltration studies on abandoned and reforested fields in central New York. Proceedings of the Eastern Snow Conference, p. 121-132.

CHAPTER 14, Worksheet 5.3a

Nomograms for estimating rainfall dispersion parameters

The formulas given in this UNIT 5.3 may be used to construct lines representing rainfall dispersion in the grid below. The resulting nomograms may be used for quick estimates of quantities dispersed.





UNIT 5.4: SNOWFALL DISPERSION

The duration of snowfall and snow accumulation results in both volume and mass considerations. Falling snow has a low density, so new-fallen snow has a greater volume per unit mass than snow that has settled for a period of time. New-fallen snow is also a good insulator. Older snow continues to increase in density at rates depenedent on snow depths and temperatures, and it also becomes a poorer insulator (see UNIT 5.1).

Snow ages due to the pressure exerted by its own mass and to changes in snow temperatures and crystal structure. The weight of its own mass increases pressure at greater depths in the snow cover, so more dense snow is found at the bottom of the snow pack. Warmer temperatures cause more rapid increases in snow densities as crystals become larger, hastening the increase in overall densities. Changes in snow characteristics result in important mechanical considerations when evaluating the relationships between wild ruminants and their winter range; snow is often a factor over much of North America in the winter as it covers forage resources and mechanically impedes movement (see CHAPTER 17).

Rapid warming trends result in rapid changes at the snow surface while the underlying snow pack changes more slowly. When such rapid warming trends occur on a daily basis, accompanied by cold nights with clear skies, the upper layer of the snow cover becomes crusty due to its higher water content and its freezing each night. Such conditions can result in a snow cover dense enough to support animals, which may, with deep snow, expose the animals to new supplies of forage at heights above their normal above-ground reach. The effects of changes in snow cover are many, and they are related to other behavioral responses which have definite effects on the ecology of wild ruminants in the winter.

REFERENCES, UNIT 5.4

SNOWFALL DISPERSION

TYPE	PUBL	CITY	PAGE	KEY WORDS---------------------	AUTHORS/EDITORS--	YEAR
aubo	rrcl	edsc	555	snow structure, ski fields	seligman,g	1962
edbo	pepr	oxen	813	p. 201-211, sym for hydro	sopper,w; lull,h,	1967

SERIALS

CODEN	VO-NU	BEPA	ENPA	KEY WORDS---------------------	AUTHORS-----------	YEAR
BAMIA	28--1	150	151	water cont, snow, cold climate	currie,bw	1947
FOSCA	8---3	225	235	elevation, aspe, cov eff water	packer,pe	1962
HILGA	22--1	1	96	influences of forest on snow	kittredge,j	1953
JFUSA	67--2	92	95	rime, hoarfrost, upper-sl	berndt,hw; fowler,	1969
JGREA	68-16	4751	4761	snow cover relations, californ	court,a	1963
JGREA	70-14	3307	3313	eddy diffusio, settl speed, sn	businger,ja	1965
JOGLA	5--41	625	636	accumulati of snow, col, influ	martinelli,m,jr	1965
SCMOA	56---	211	231	perennial snow and glaciers	church,je	1943
TAGUA	42...	----	----	folklore about snowfall interc	miller,dh	1961
WRERA	3---4	1035	1039	snow catch, conifer crown	satterlund,dr; hau	1967
WRERA	6....	649	652	disposition of snow, conif cro	satterlund,dr; hau	1970
WTHWA	18--6	247	251	measure snowpack prof, radioac	smith,jl; willen,/	1965
WUAEA	.....	1	64	washington climate, count	phillips,el	1965
XAFNA	138--	1	16	snow accumula, melt, adirondac	lull,hw; rushmore,	1960
XANEA	34---	1	16	surface geomet, loss interc sn	satterlund,dr; esc	1965
XAPWA	18---	1	24	intercept process durin snowst	miller,dh	1964
XCTAA	.....	----	----	snow hydrology	us dept of commerc	1956
XFNNA	116--	1	4	snow and frost in adirondacks	lull,hw; rushmore,	1961

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Billelo, M. 1957. A survey of arctic snow cover properties as related to climatic conditions. International Association of Sci. Hydrology, General Assembly of Toronto. 1957 IV pp. 63-77.

Cooperative Watershed-Management Research Unit. The surface geometry of a closed conifer forest in relation to losses of intercepted snow. New York State University College of Forestry and U. S. Forest Service, Northeastern Forest Experiment Station, Syracuse, New York.

Kuzmin, P. P. 1956. Determination of the coefficient of reflection of snow cover by the method of successive approximation. In: Snow and snowmelt, their study and use. Akad. Nauk SSSR. Institute Geografii, Moscow: 30-43.

U. S. Army Corps of Engineers. 1956. Snow Hydrology. North Pacific Division, Portland, Oregon. 437 p.

CLOSING COMMENTS

Meteorology and thermal characteristics of different habitats have been introduced in CHAPTER 14. These characteristics are used in analyses of thermal exchange, an important consideration when evaluating physiological and behavioral responses, especially when animals are in critical thermal environments, which are discussed in CHAPTER 16, TOPIC 3.

The next chapter (CHAPTER 15) includes discussions of basic thermal exchange. The discussions refer back to this CHAPTER 14, and are the basis for further discussions in CHAPTER 16.

Aaron N. Moen
March 27, 1981

GLOSSARY OF SYMBOLS USED - CHAPTER FOURTEEN

ABCO = Absorption coefficient of the soil
ABHU = Absolute humidity
ABTE = Absolute temperature
ADTC = Average daily temperature in Celsius
ADTE = Average daily temperature
AITC = Air temperature in Celsius
AITE = Air temperature
AMPL = Amplitude of the variation from MPRA
AVPA = Actual vapor pressure of the air

CMMT = Calculated mean monthly temperature
CPCM = Calories per square centimeter per minute
CSCD = Calories per square centimeter per day

DUPH = Duration of precipitation in hours

ERTK = Effective radiant temperature in °K

HGTC = Height in centimeters
HGHT = Height
HOUR = Hour of the day

IREM = Infrared emissivity

JDAY = Julian day
JDMA = Julian day at the maximum

KMTH = Kilocalories per square meter per hour

MAWV = Mass of water vapor
MMHG = Millimeters of mercury
MMTC = Mean monthly temperature in Celsius
MPRA = Midpoint radiation value
MPTE = Midpoint temperature

PCMH = Precipitation in centimeters per hour
PICH = Precipitation intensity in centimeters per hour
PRPC = Primary phase correction
PTRH = Percent relative humidity

QREE = Quantity of radiation emitted

REHU = Relative humidity
ROMH = Runoff in cubic meters per hectare

SAVP = Saturation vapor pressure
SBCO = Stefan-Boltzmann constant
SORA = Solar radiation
SPHU = Specific humidity

TERA = Temperature range over the year
TMAI = Total mass of air
TPMH = Total precipitation in cubic meters per hectare
TVMA = Total volume of moist air

VPDE = Vapor pressure deficit

WAMH = Water in the soil per cubic meters per hectare
WIVE = Wind velocity
WLME = Wavelengths of maximum emission

GLOSSARY OF CODENS - CHAPTER FOURTEEN

SERIALS are identified by five-character, generally mnemonic codes called CODEN, listed in 1980 BIOSIS, LIST OF SERIALS (BioSciences Information Service, 2100 Arch Street, Philadelphia, PA 19103).

The headings for the lists of SERIALS are:

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

The volume and issue numbers (VO-NU) are given after the CODEN entry, followed by beginning page (BEPA), ending page (ENPA), species discussed (ANIM), KEY WORDS from the title, AUTHORS [truncated if necessary, slash (/) indicates additional authors], and year.

AFJZA Allgemeine Forst und Jagdzeitung
AGJOA Agronomy Journal
AGMYA Agricultural Meteorology
AJBOA American Journal of Botany
AMGBA Archiv fuer Meteorologie Geophysik und Bioklimatologie, Serie B
ANBOA Annals of Botany (London)
ANSFA Annales des Sciences Forestieres (Paris)
APOPA Applied Optics
AUFOA Australian Forestry

BAMIA Bulletin of the American Meteorological Society
BEGOA Gerlands Beitraege zur Geophysik
BOZHA Botanichnyi Zhurnal (Kiev)
BPYAA Beitraege zur Physik der Atmosphaere
BTBCA Bulletin of the Torrey Botanical Club
BUGMA Bulletin of the Geological Society of America

CIEGA Civil Engineering
CJASA Canadian Journal of Agricultural Science
CJBOA Canadian Journal of Botany (Canada)
CJFRA Canadian Journal of Forest Research
CJSSA Canadian Journal of Soil Science
CJTEA Canadian Journal of Technology
CSTNA Castanea
CWBSA Commonwealth Bureau of Soils Technical Communication

EAFJA East African Agriculture Forestry Journal
ECMOA Ecological Monographs
ECOLA Ecology
EMFRA Empire Forestry Review
ENREA Engineering News-Record

FIRAD Fiziologiya Rastenii (Moscow)
FOSCA Forest Science
FRSTA Forestry (England)

GFRPA Georgia Forest Research Paper
GPNOA Geofysike Publikasjoner (also listed as Geophysica Norvegica)

HFOPA Harvard Forest Papers
HILGA Hilgardia
HYSBA Hydrological Sciences Bulletin (formerly Bulletin of the International Association of Scientific Hydrology)

IAXNA Forestry Note
IJBMA International Journal of Biometeorology
IRFOA Irish Forestry

JAGRA Journal of Agricultural Research
JAMOA Journal of Applied Meteorology
JAPEA Journal of Applied Ecology (England)
JECOA Journal of Ecology
JFUSA Journal of Forestry
JGREA Journal of Geophysical Research
JOGLA Journal of Glaciology
JRCEA Journal of the Irrigation and Drainage Division, American Society of Civil Engineers
JRMGA Journal of Range Management
JSWCA Journal of Soil and Water Conservation
JVAHA Journal of Veterinary and Animal Husbandry Research
JWMAA Journal of Wildlife Management
JYCEA Journal of the Hydraulics Division, American Society of Civil Engineer

LESOA Lesovedenie (USSR)

MMONA Meteorological Monographs (American Meteorological Society)
MWREA Monthly Weather Review

NASRA National Academy of Sciences--National Research Council, Publication

OJSCA Ohio Journal of Science (US)

PAEBA Engineering Research Bulletin (Pennsylvania State University, College of Engineering)
PHDSA Proceedings of the Hydrology Symposium
PRSLA Proceedings of the Royal Society of London
PSAFA Proceedings of the Society of American Foresters
PTRMA Philosophical Transactions of the Royal Society of London
PVDEA Pochvovedenie

QJFOA Quarterly Journal of Forestry
QJRMA Quarterly Journal of the Royal Meteorological Society

SCIEA Science
SCMOA Scientific Monthly
SIFEA Silva Fennica
SOSCA Soil Science
SSSAA Soil Science Society of America, Proceedings
SSSCA Soviet Soil Science

TAAEA Transactions of the ASAE (American Society of Agricultural Engineers)
TACEA Transactions of the American Society of Civil Engineers
TAGUA Transactions of the American Geophysical Union
TFSOA Transactions of the Faraday Society

UUARA Utah Agricultural Experiment Station Special Report

WRERA Water Resoures Research
WTHWA Weatherwise
WUAEA Washington State University, Extension Service, Extension Bulletin

XAARA U S Department of Agriculture, Agricultural Research Service (ARS Series or Report)
XAFNA Northeastern Forest Experiment Station, Station Paper
XAFNB U S Forest Service Research Note NC
XAGCA U S D A Circular
XAMPA U S D A Miscellaneous Publication
XANEA U S Forest Service Research Paper NE
XAPWA U S Forest Service Research Paper PSW
XASEA U S Forest Service Research Paper SE
XATBA U S D A Technical Bulletin
XCTAA U S Department of Commerce, Office of Technical Services, AD
XFGTA U S Forest Service General Technical Report NC
XFNNA U S Forest Service Research Note NE
XFRMA U S Forest Service Research Paper RM
XFTBA U S Forest Service Technical Bulletin
XIPPA Geologic Survey Professional Paper
XIWSA Geological Survey Water-Supply Paper
XPNWA U S Forest Service Research Note PNW

YAXAA U S D A Yearbook of Agriculture

LIST OF PUBLISHERS - CHAPTER FOURTEEN

The headings for the lists of BOOKS are:

TYPE PUBL CITY PAGE ANIM KEY WORDS----------------- AUTHORS/EDITORS-- YEAR

All essential information for finding each book in the library is given on just one line. The TYPE of book could have either AUTHORS (aubo) or EDITORS (edbo). Publishers (PUBL) and CITY of publication are given with four-letter mnemonic symbols defined below. The PAGE column gives the number of pages in the book; ANIM refers to the species discussed in the book (given as a four-letter abbreviation of genus and species), and KEY WORDS listed are from the title. The AUTHORS/EDITORS and YEAR of publication are given in the last two columns.

acpr	Academic Press	New York	nyny
adwe	Addison-Wesley	Reading,MA	rema
amsa	Amer. Soc. of Agronomy	Madison, WI	mawi
cnha	Chapman & Hall	London	loen
copr	Columbia Univ.	New York	nyny
crcp	CRC (Chem. Rubber Co.) Press	Cleveland, OH	cloh
cupr	Cambridge Univ. Press	Cambridge, England	caen
dove	Dover Publishing Company	New York	nyny
else	Elsevier	New York	nyny
gidr	Girdrometeoizdat	Leningrad, Russia	leru
haro	Harper and Row	New York	nyny
haup	Harvard Univ. Press	Canbridge, MA	cama
hrwi	Holt, Rhinehart, & Winston, Inc.	New York	nyny
jdco	John Day	New York	nyny
jwed	J. W. Edwards, Inc	Ann Arbor, Michigan	aami
jwis	John Wiley & Sons, Inc.	New York	nyny
mhbc	McGraw-Hill Book Co., Inc.	New York	nyny
pepr	PergamonPress	Oxford,England	oxen
prha	Prentice-Hall, Inc.	Englewood Cliffs, NJ	ecnj
ropr	Ronald Press	New York	nyny
repu	Reinhold Publishing	New York	nyny
rrcl	R. R. Clarke Ltd.	Edinburgh, Scotland	edsc

uchp	Univ. of Chicago Press	Chicago, IL	chil
unca	Univ. of California, Davis	Davis, CA	daca
ugap	Univ. of Georgia Press	Atlanta, GA	atga
weni	Weidenfeld & Nicholson	London	loen
whfr	W. H. Freeman Co.	San Francisco, CA	sfca

GLOSSARY OF ANIMAL CODE NAMES

Wild ruminants are referred to in this CHAPTER by a 4-character abbreviation from the family, genus and genus-species. These are listed below under Abbreviation.

Scientific names of North American wild ruminants are those used in BIG GAME OF NORTH AMERICA, edited by J.C. Schmidt and D. L. Gilbert (1979: Stackpole Books, Harrisburg, PA 17105, 494 p.), and may be different from the scientific names given in the original literature.

The abbreviations used for North American wild ruminants are listed below.

CLASS: MAMMALIA

ORDER: ARTIODACTYLA	Abbreviation
FAMILY: CERVIDAE	cerv
GENUS: *Odocoileus* (deer)	od--
SPECIES: *O. virginianus* (white-tailed deer)	odvi
O. hemionus (mule deer)	odhe
GENUS: *Cervus* (Wapiti, elk)	ce--
SPECIES: *C. elaphus*	ceel
GENUS: *Alces* (moose)	
SPECIES: *A. alces*	alal
GENUS: *Rangifer* (caribou)	
SPECIES: *R. tarandus*	rata
FAMILY: ANTILOCAPRIDAE	
GENUS: *Antilocapra*	
SPECIES: *A. americana* (pronghorn)	anam
FAMILY: BOVIDAE	bovi
GENUS: *Bison* (bison)	bi--
SPECIES: *B. bison*	bibi
GENUS: *Ovis* (sheep)	ov--
SPECIES: *O. canadensis* (bighorn sheep)	ovca
O. dalli (Dall's sheep)	ovda
GENUS: *Ovibos*	
SPECIES: *O. moschatus* (muskox)	obmo
GENUS: *Oreamnos*	
SPECIES: *O. americanus* (mountain goat)	oram

The abbreviations used for European wild ruminants are listed below.

CLASS: MAMMALIA

	Abbreviation
ORDER: ARTIODACTYLA	
FAMILY: CERVIDAE	cerv
GENUS: Capreolus (roe deer)	ca--
SPECIES: C. capreolus	caca
GENUS: Dama (fallow deer)	da--
SPECIES: D. dama	dada
GENUS: Cervus (Wapiti, elk)	ce--
SPECIES: C. elaphus (red deer)	ceel
GENUS: Alces (moose)	
SPECIES: A. alces	alal
GENUS: Rangifer (caribou)	
SPECIES: R. tarandus	rata
FAMILY: BOVIDAE	
GENUS: Bison (bison)	
SPECIES: B. bonasus	bibo
GENUS: Capra (ibex, wild goat)	cp--
SPECIES: C. aegagrus (Persian ibex)	cpae
C. siberica (Siberian ibex)	cpsi

OTHERS

Abbreviations for a few other species and groups of species may appear in the reference lists. These are listed below.

Axis axis (axis deer)	axax
Elaphurus davidianus (Pere David's deer)	elda
Cervus nippon (Sika deer)	ceni
Hydropotes inermis (Chinese water deer)	hyin
Muntiacus muntjac (Indian muntjac)	mumu
Moschus moschiferus (musk deer)	momo
Ovis nivicola (snow sheep)	ovni
Ovis musimon (moufflon)	ovmu
Ovis linnaeus (Iranian sheep)	ovli
Rupicapra rupicapra (chamois)	ruru
big game	biga
domestic sheep	dosh
domestic cattle	doca
domestic goat	dogo
domestic ruminant	doru
herbivore	hrbv
mammals	mamm
three or more species of wild ruminants	many
ruminants	rumi
ungulates	ungu
vertebrates	vert
wildlife	wldl
wild ruminant	wiru

JULIAN DAY: MONTH AND DAY EQUIVALENTS*

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	1
2	002	033	061	092	122	153	183	214	245	275	306	336	2
3	003	034	062	093	123	154	184	215	246	276	307	337	3
4	004	035	063	094	124	155	185	216	247	277	308	338	4
5	005	036	064	095	125	156	186	217	248	278	309	339	5
6	006	037	065	096	126	157	187	218	249	279	310	340	6
7	007	038	066	097	127	158	188	219	250	280	311	341	7
8	008	039	067	098	128	159	189	220	251	281	312	342	8
9	009	040	068	099	129	160	190	221	252	282	313	343	9
10	010	041	069	100	130	161	191	222	253	283	314	344	10
11	011	042	070	101	131	162	192	223	254	284	315	345	11
12	012	043	071	102	132	163	193	224	255	285	316	346	12
13	013	044	072	103	133	164	194	225	256	286	317	347	13
14	014	045	073	104	134	165	195	226	257	287	318	348	14
15	015	046	074	105	135	166	196	227	258	288	319	349	15
16	016	047	075	106	136	167	197	228	259	289	320	350	16
17	017	048	076	107	137	168	198	229	260	290	321	351	17
18	018	049	077	108	138	169	199	230	261	291	322	352	18
19	019	050	078	109	139	170	200	231	262	292	323	353	19
20	020	051	079	110	140	171	201	232	263	293	324	354	20
21	021	052	080	111	141	172	202	233	264	294	325	355	21
22	022	053	081	112	142	173	203	234	265	295	326	356	22
23	023	054	082	113	143	174	204	235	266	296	327	357	23
24	024	055	083	114	144	175	205	236	267	297	328	358	24
25	025	056	084	115	145	176	206	237	268	298	329	359	25
26	026	057	085	116	146	177	207	238	269	299	330	360	26
27	027	058	086	117	147	178	208	239	270	300	331	361	27
28	028	059	087	118	148	179	209	240	271	301	332	362	28
29	029	[060]	088	119	149	180	210	241	272	302	333	363	29
30	030		089	120	150	181	211	242	273	303	334	364	30
31	031		090		151		212	243		304		365	31

* For leap year, February 29 = JDAY 60. Add 1 to all subsequent JDAYs.

LIST OF WORKSHEETS - CHAPTER FOURTEEN