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Nongrowing Season ET from Irrigated Fields

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Abstract

The evaporative loss of water from agricultural fields during the nongrowing season is an important component of the annual water balance of irrigated lands. This study was conducted to measure daily ET from clipped grass and fallow fields from October through March and to compare the ET with precipitation received during the same period. Two weighing lysimeters near Kimberly, Idaho, were used to measure daily ET for six nongrowing seasons, from 1985 through 1991. ET averaged about 1 mm/day during the 6-month season, and total ET exceeded precipitation except for the 1985-86 period. ET from the grass lysimeter exceeded that from the mostly fallow lysimeter in early fall while the reverse was true during late winter. The results indicate that there is little, if any, potential for a net increase in stored soil water during the nongrowing season when fields receive an early or mid-fall irrigation in southern Idaho.

Introduction

Information about the evaporative loss of water from agricultural land during the nongrowing season is needed to develop the annual water balance for that land. Even though a harvestable crop may not be growing on a field during the dormant season in regions with arid temperate climates, some evaporation occurs from exposed soil surfaces, weeds or crop regrowth, and from snow cover. The ability to account for nongrowing season evaporation is often essential in developing schemes for reducing irrigation requirements while also reducing the leaching of chemicals below the soil root zone. Nongrowing season evaporation is also an

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important component of the hydrologic balance of unirrigated agriculture lands, natural rangelands, wetlands, and watersheds.

Very little quantitative information is available about ET during the nongrowing season. It is generally even more difficult to determine ET during wintertime when ET rates are low and meteorological conditions are highly variable than during summer periods when ET rates are high and meteorological conditions are relatively consistent. A major difficulty in determining the total ET during the nongrowing season is in measuring the rate of evaporation, or sublimation, of water from snow and frozen, exposed soil surfaces. Some research has attempted to characterize the melting of a snow cover using micrometeorological and energy balance approaches (Granger and Male, 1978; McKay and Thurtell, 1978; Halberstam and Schieldge, 1981; and Nkemdirim, 1991), but these studies have been for selected periods with fairly stable weather conditions and have not provided total evaporative losses for the entire season.

The purpose of this study was to measure the daily evaporation of water from agricultural fields during the nongrowing season, using weighing lysimeters, for several years, and to determine the general nature of the seasonal evaporative water loss from irrigated fields in comparison with precipitation received during the same period. The research utilized an existing weighing lysimeter installation established to determine the water requirements of irrigated crops. The lysimetric approach provides a direct measure of the evaporative loss of water from the lysimeter surface, and is well suited for obtaining continuous data for extended time periods. The six-month period from October through March was considered to be the nongrowing season for this study because many fields are then in a dormant or fallow condition in southern Idaho and other similar areas. A continuous record of daily evaporation was desired to provide a seasonal total including evaporation on all types of days. For purposes of this study, the measured evaporative loss is referred to as evapotranspiration (ET) because some transpiration does occur during this period, even though much of the evaporation occurs directly from soil, crop residues, or as sublimation of snow cover.

Initial stages of the research showed that it was impossible to determine evaporation from a snow cover with a weighing lysimeter when a crust formed on the snow surface or when snow drifted across the lysimeter. This necessitated developing procedures to solve the problems of crusting and drifting. Ultimately, data were obtained with the weighing lysimeters for the October through March period from 1985 through 1991 (about 1080 days of data).

Experimental Site and Procedures

Research was conducted at the USDA, Agricultural Research Service lysimeter site about 1 km east of Kimberly, Idaho, at 42° 33' N, 114° 21' W and 1207 m elevation. The climate of the area is arid, temperate with a 50% probability of minimum air temperatures (temps) declining to 0°C by 24 September and −4°C by 23 October. Likewise, air temps may be less than −4°C until after 10 April and less than 0° until after 13 May. The normal maximum and minimum air temps on 1 October are 20.6° and 2.8°C respectively. During the coldest part of the winter, early January, the respective normal temps are 1.1 and −8.3. By the end of March, they are 12.2 and −1.1 (USCOM-NOAA, 1993).

One weighing lysimeter (Lys. 1) was planted to grass throughout the six-year period of the study. It was located in the center of a 0.9 ha, rectangular, grass plot, about 200 m east to west by 45 m north to south. The grass plot was the center plot of a 2.6 ha field. A second identical lysimeter (Lys. 2) was located near the center of a square, 2.2-ha field immediately west of the Lys. 1 field (see Wright, 1988 and 1991, for more detailed descriptions of the lysimeters and the study site). Lys. 2 and its field were in fallow condition during most of the study periods, depending on the cropping sequence. Each lysimeter had at least 75 m of wind fetch over surfaces similar to the lysimeter surface with predominantly westerly or easterly winds.

The lysimeter soil bin was 1.83 m square by 1.22 m deep and was mounted on a mechanical floor stand scale. The scale system forces were transferred to an electronic load cell. Evaporative loss of water from the lysimeter surface caused a decrease in load cell tension. Load cell signals were continuously recorded with strip chart recorders and a data system. The load cell power supply voltages were recorded with the data system. During data analysis, the strip charts, which provided a visual record of all lysimeter mass changes, were manually digitized and load cell data were adjusted for the effects of irrigation, precipitation, snow crusting and drifting, and management operations. Load cell data were converted to an equivalent water depth per unit surface area assuming a water density of 1.0 Mg m^{-3} and a mid-rim to mid-rim surface area of 3.44 m^2. Daily ET was calculated from midnight to midnight. The field capacity water content of the Portneuf silt loam soil at the site averages about 30% for the 1.2-m soil bin depth (360 mm water depth equivalent). The combined accuracy of the lysimeter system was about 250 g, or 0.07 mm water depth equivalent.

At the beginning of the snow season, heating "rings" were placed on the pliable seal of the lysimeter rim to prevent bridging within the snow layer between the lysimeter and the surrounding area. The square heating ring was constructed from 1/2-inch (1.27-cm) steel conduit. Self-temperature regulating, pipe heating cable was inserted inside the conduit and connected to an AC power source. Small pins were driven into the soil to horizontally anchor the heating ring. When snow accumulation exceeded the capacity of the heating ring, the lysimeter snow surface was "cut" loose from the surrounding snow layer to alleviate bridging effects. The lysimeter sites were usually visited daily, especially during periods of snow cover, to monitor surface conditions and snow depth, crusting and drifting.

Two parallel rows of snow fencing were placed on the east and west flanks of Lys. 1 to alleviate drifting during the wintertime periods, except for the 1985-86 period when it snowed before the fencing was erected. The rows of snow fence were 30 m long and 8 m apart, with the innermost row 8 m from the edge of the lysimeter. Snow fencing was not erected at the Lys. 2 site. When drifting occurred across Lys. 2, Lys. 1 data were substituted to provide complete daily records for Lys. 2.

Precipitation data used in this study were collected by the National Weather Service (NWS) at their climatological station near the USDA-ARS laboratory complex, about 1 km north of the lysimeter site, using a standard, shielded 8-in. (20.3 cm) weighing rain gauge.

The grass of Lys. 1 and the surrounding plot was mowed periodically to keep it 8 to 15-cm tall, except in 1989 when the grass strip was managed for grass hay. In that case, the grass was not cut after the final harvest on 10 September. The grass plot received a final irrigation each fall in late September or early October so it entered the study period in a well-watered condition. The cropping sequence of Lys. 2 was such that it entered the six-month study period each year in various but mostly fallow conditions. Whenever the field was tilled with a tractor, the soil surface on and around Lys. 2 was hand tilled to simulate as closely as possible the field surface condition. In 1985 the alfalfa crop on Lys. 2 was spray killed on 20 September. The field was then disked on 25 October and was not retilled until after 1 April. In 1986, following the harvest of dry beans in September, Lys. 2 and field were planted to winter wheat on 16 October and were sprinkler irrigated on 18 October to germinate the wheat. In 1987, the field consisted of wheat stubble until 27 October, when it was disked and plowed and left in the rough-plowed condition until late April. A crop of sprinkler irrigated potatoes was harvested in mid-October, 1988, after which the field was disked and left in that condition through the winter. Sugarbeets grown on Lys. 2 and field in 1989 were harvested on 25 October, after which the field was disked and no further tillage was performed until April 1990 when alfalfa was seeded with a pea crop. The new seeding alfalfa was harvested on 25 September 1990 and was fall irrigated on 8 October.

Results and Discussion

During previous attempts to measure the evaporative loss of water from snow covered lysimeters, I found that a stiff crust on the surface of the snow layer caused the apparent mass of the system to increase or decrease with time. This "bridging" effect of the snow crust (no doubt the result of stress and strain relationships within the crust) completely masked the effects of snow sublimation. The heating rings used on the lysimeter rims alleviated this problem during periods of snow cover by creating a gap in the snow cover of the lysimeter and the surrounding area. The heating cable within the heating rings provided sufficient heat to form the gap except during periods of heaviest snowfall or drifting. When the heating rings did not prevent bridging, a slit about 1 cm wide was manually cut through the snow layer to the depth of the heating ring. The heating rings were disconnected from the power source when not needed to prevent bridging.

In addition to the crusting problem, my earlier research with lysimeters in wintertime had shown that during periods of drifting, the mass of snow on the lysimeter changed so erratically that it was impossible to resolve the evaporation component. Neglecting days with drifting was not feasible because of the frequency with which drifting occurs in southern Idaho. During days on which drifting occurs, the weather conditions usually have the highest potential for sublimation of snow, because in addition to the high wind levels, skies are often clear and relative humidity is low. The two parallel rows of snow fencing caused snow to be deposited between the rows on the upwind side of the lysimeter and prevented snow from drifting across the lysimeter and the area between the fencing on either side of the lysimeter. During snowfall, a continuous blanket of snow accumulated across the lysimeter and its surroundings somewhat proportional to the rate of precipitation. While the fencing prevented drifting, it still allowed a relatively high flow of air across the lysimeter compared to calm conditions. Therefore, even though the diminished wind speed, due to the fencing, may have reduced the potential for turbulent mixing within the surface-air-layer, this approach permitted the resolution of the existing rate of sublimation which likely was energy limited under such conditions, anyway.

Daily ET was measured with the lysimeters for about 180 days each season, providing about 1080 days of data for the six seasons. The lysimeters had 50% or greater snow cover for about 242 days of the 1080 days. Daily ET data for the six-month period are shown as a scatter diagram for all six seasons in Fig. 1 for Lys. 1 and Fig. 2 for Lys. 2, beginning with day of year (DOY) 274 (1 Oct) through DOY 90 (31 Mar). Lys. 1 with a transpiring grass cover usually had higher ET rates in the early fall than did Lys. 2, which frequently had bare soil during that time. ET rates during December and January were similar for the two lysimeters, except for days when Lys. 2 ET rates were much higher than Lys. 1 rates. This occurred when Lys. 2 had a bare, wet, unfrozen surface soil on days with high drying potential, while Lys. 1 had a dormant grass cover which insulated the surface and restricted evaporation. Zero daily ET occurred during periods of heavy cloud cover, fog, and rain or snow.

Cumulative ET and WSO precipitation (WS PPT) are shown for Lys. 1 and Lys. 2 in Fig. 3 for 1985-86 and in Fig. 4 for 1988-89, two seasons with quite different precipitation amounts. Cumulative Lys. 1 grass ET steadily increased in both cases from 1 October until early November (DOY 310) when grass transpiration mostly ceased. On the average during that 35-day period, bare soil ET was about 25% of grass ET. During the 1985-86 period, grass ET exceeded precipitation until about DOY 345 after which ET was less than precipitation.

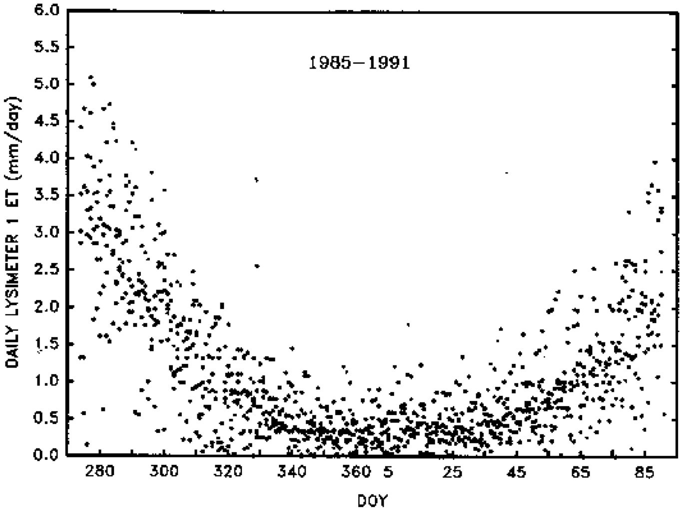

Figure 1. Daily Nongrowing Season ET Measured with a Grass Lysimeter.

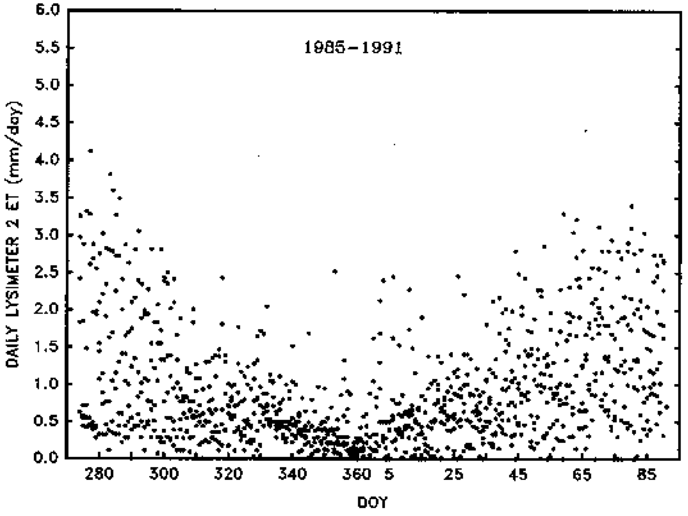

Figure 2. Daily Nongrowing Season ET Measured with a Mostly Fallow Lysimeter.

ET from the dead alfalfa stubble (Lys. 2) was less than precipitation from DOY 310 on. The lysimeters were snow covered for about 91 days of the 182-day period in 1985-86 and had continuous snow cover for about 80 days, from mid-November until late January. This was the longest period of continuous snow cover of any of the years studied. Lys. 2 had mostly a bare soil surface when not snow covered. In contrast, during the 1988-89 period the lysimeters had complete snow cover for only about 20 days. Late winter evaporation from Lys. 2 was relatively high and kept pace with precipitation received during that time (see Fig. 4).

Total monthly, seasonal, and mean daily ET are listed in Table 1 for both lysimeters along with WS PPT for all six years of the study. The grass on Lys. 1 remained green and at least partially active during most years until mid-November when grass top growth was usually killed by freezing weather or was buried in snow. Grass "green-up" and regrowth usually began in mid-March. In 1985 Lys. 2 had dead alfalfa stubble from DOY 274 through DOY 298 after which it was bare, tilled soil until after DOY 90 the next spring. In 1986, the winter wheat planted on Lys. 2 emerged in early November, but was mostly dormant until mid-March (DOY 75) the following spring. Lys. 2 was in a fallow condition throughout the 1987-88 and 1988-89 periods. Total October ET in 1989 was about the same for Lys. 1 and Lys. 2 because sugarbeets were actively transpiring on Lys. 2 until late October, DOY 298. The surface of Lys. 2 was in a fallow condition after harvest of sugarbeets. In 1990, the alfalfa on Lys. 2 was 7.5 to 12.5 cm tall by the end of October, DOY 304, and became dormant by mid-November, about DOY 320. The alfalfa did not begin growing before the end of March.

Total ET for Lys. 1 was greater than for Lys. 2 for all years except 1990-91, when total amounts were about equal, primarily because Lys. 1 had higher ET in October than Lys. 2 (see Table 1). Lys. 2 had higher average ET for the February-March period than Lys. 1. Overall average daily ET for Lys. 1 (1.09 mm/day) was about 20% greater than for Lys. 2 (0.87 mm/day). Total ET for Lys. 1 and Lys. 2 was greater than precipitation in all years except 1985-86. The 30-year normal precipitation for the October through March period is 155 mm (USCOM-NOAA, 1993). Thus, total precipitation for the six-month periods from 1985 through 1991 was 155, 88, 65, 105, 80, and 63 percent of normal, respectively, and overall average precipitation was 92 percent of normal. In spite of the wide range in total seasonal precipitation (CV = 35.8%), total seasonal ET for Lys. 1 was fairly consistent for all six years (CV = 5.4%) because of the early fall irrigation. Overall ET averaged 1.1 mm/day for Lys. 1 and 0.9 mm/day for Lys. 2, or 1.0 mm/day averaging Lys. 1 and Lys. 2. For December and January, the average ET of both lysimeters was 0.47 mm/day. The average ET of Lys. 1 for the 242 days with 50% or greater snow cover was 0.42 mm/day. Average March ET for both lysimeters was about 35% greater than precipitation. When the month of October was excluded from the nongrowing season total, the six-year

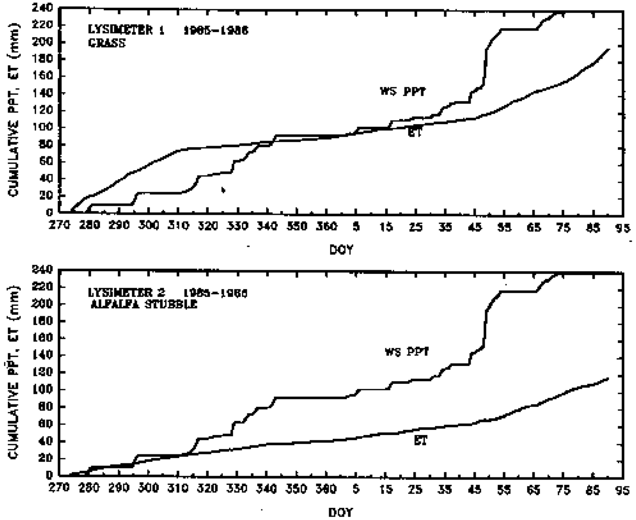

Figure 3. Nongrowing Season, Cumulative Precipitation and ET for a High Snow Season.

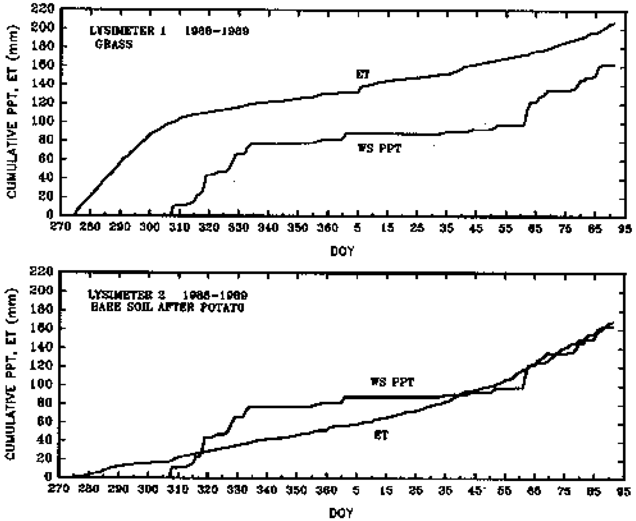

Figure 4. Nongrowing Season, Cumulative Precipitation and ET for a Low Snow Season.

Table 1. Nongrowing season monthly, seasonal, and mean daily ET, as measured with Lys. 1 and Lys. 2, and Weather Service precipitation (WS PPT) for the six-year period 1985-91, Kimberly, Idaho.

	Total (mm)						
Year	Oct	Nov	Dec	Jan	Feb	Mar	Total
			Lys. 1				
1985-86	64	18	11	15	27	63	198
1986-87	75	30	10	9	14	38	177
1987-88	91	24	13	11	20	42	201
1988-89	96	23	13	19	21	34	207
1989-90	67	32	14	15	17	55	200
1990-91	81	41	18	11	14	41	205
Mean	79.0	28.3	12.9	13.5	19.0	45.5	198.1
Daily	2.6	.9	.4	.4	.7	1.47	1.1
			Lys. 2				
1985-86	21	14	9	14	22	39	118
1986-87	30	26	7	13	23	56	155
1987-88	49	17	16	25	35	41	184
1988-89	17	22	18	23	35	53	168
1989-90	66	18	10	22	22	30	167
1990-91	64	31	18	18	23	49	204
Mean	41.0	21.3	13.2	19.2	26.5	44.7	165.9
Daily	1.3	.7	.4	.6	1.0	1.4	.9
			WS PPT				
1985-86	24	48	20	26	100	17	235
1986-87	26	15	2	33	24	37	137
1987-88	1	26	29	21	3	21	101
1988-89	0	77	0	5	10	65	157
1989-90	36	28	1	32	3	25	125
1990-91	8	14	17	17	7	35	97
Mean	15.9	34.1	11.4	22.2	24.6	33.3	142.1
Daily	.5	1.2	.4	.7	.9	1.1	.8

average seasonal ET was essentially the same for Lys. 1 and Lys. 2, 119 and 117 mm, respectively, compared to the average precipitation for the same five-month period of 126 mm.

Conclusions

With the climatic situation of southern Idaho, when fields received a fall irrigation, the ET from a mostly bare soil lysimeter exceeded precipitation during five of the six seasons of study for the six-month nongrowing season, October through March. Seasonal precipitation for the year of exception was 55% greater than the 155-mm normal amount for the season. On the average, October ET from a grass lysimeter was 40 mm greater than ET from a mostly bare soil lysimeter, but ET from the two lysimeter surfaces was similar for the November through March period. Total seasonal ET was less variable from season to season than was precipitation. ET in excess of precipitation for five of the six seasons resulted in a depletion of available soil water averaging about 75 mm for the grass lysimeter and 52 mm for the mostly bare lysimeter. During those years, precipitation averaged 31 mm below normal.

The results indicate that if a water management goal is to maximize the soil storage of nongrowing season precipitation, while also minimizing the leaching of chemicals from the root zone, then irrigated lands similar to those of the area of study should not be fall irrigated. For wetlands or nonirrigated areas where early fall precipitation exceeds 100 mm, and climate is otherwise similar to southern Idaho, the results of this study indicate that ET would be about 180 mm, depending on plant growth and soil cover conditions. This evaporative water loss, which may well be higher than previously estimated, would be applicable in estimating the hydrological water balance for such areas during the nongrowing season.

APPENDIX 1. REFERENCES

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