Water Savings from Crop Residue in Irrigated Corn

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Introduction

During the past 10-15 years, there has been a great deal of emphasis in sprinkler applications to move closer to the target. The thinking has been to decrease the exposure to potential evaporation in the air. At the same time sprinkler manufacturers have produced heads with lower operating pressures producing fewer fine spray particles leaving far fewer particles subject to evaporation. The result is that application efficiencies have improved.

What remains are the same wet soil surfaces beneath the crop canopies. We need to spread the water to gain infiltration, but then evaporation from the soil surface takes over after irrigation stops. It has been assumed that evaporation from the soil surface in irrigated crop canopies is relatively small. The objective of this paper is to report on some of the research in the area of evaporation from soil surfaces.

Evaporation-Transpiration Partition

Transpiration, or the process of water evaporating near the leaf and stem surfaces, is a necessary function for plant life. It is literally the final driving force for water flow through the plant. It provides plant cooling. Transpiration relates directly to grain yield in the crops we produce. Transpiration rates are driven by atmospheric conditions and by the crop's growth stage. As a crop grows it requires more water until it matures and generally reaches a plateau. Daily weather demands cause fluctuations in transpiration as a result. Soil water begins to limit transpiration when the soil dries below a threshold generally half way between field capacity and wilting point. Irrigation management usually calls for scheduling to avoid water stress.

Evaporation from the soil surface may have some effect on transpiration in the influence of humidity in the crop canopy. However, the mechanisms controlling evaporation from soil are independent of transpiration. The combined processes of evaporation from soil (E) and transpiration (T) are measured together as evapotranspiration (ET) for convenience. Independent measurements of E and T are difficult. Independent measurements are becoming more important as we strive to tighten management of sprinkler irrigation to achieve more efficient water use.

Field research has shown that in sprinkler irrigated corn as much as 30% of total evapotranspiration is consumed as evaporation from the soil surface (Klocke et. al., 1985). These results were from bare soil conditions for sandy soils with sprinkler irrigation. For a corn crop with total ET of 30 inches, 9 inches would be going to soil evaporation and 21 inches to transpiration. This indicates a window of opportunity if the unproductive soil evaporation component of ET can be reduced without reducing transpiration.

Evaporation from Soil Trends

Evaporation from the soil surface after irrigation or rainfall is controlled first by the atmospheric conditions and by the shading of a crop canopy if applicable. Water near the surface readily evaporates and does so at a rate that is only limited by the energy available. This so called energy limited evaporation lasts as long as a certain amount of water that evaporates, 0.47 in (12 mm) for sandy soils and 0.4 in (10.2 mm) for silt loam soils. The time it takes to reach the energy limited evaporation depends on the energy available from the environment. Bare soil with no crop canopy on a sunny hot day with wind receives much more energy than a mulched soil under a crop canopy on a cloudy cool day with no wind.

After the threshold between energy limited and then soil limited evaporation is reached, evaporation is controlled by how fast water and water vapor can move through the soil to the soil surface. The relationships that have been developed to describe soil limited evaporation are shown in Fig 1 for a silt loam soil. There is a diminishing rate of evaporation with time as the soil surface dries. The soil surface insulates itself from drying as it takes longer for water or vapor to move through the soil to the surface.

The challenge for sprinkler irrigation is the high frequency that the soil surface is put into energy limited evaporation. With twice-weekly irrigation events it is likely that the soil surface will be in the higher rates of energy limited evaporation during the entire growing season. Only during the early growing season with infrequent irrigations and little canopy development would there be a possibility for lower rates of soil limited evaporation.

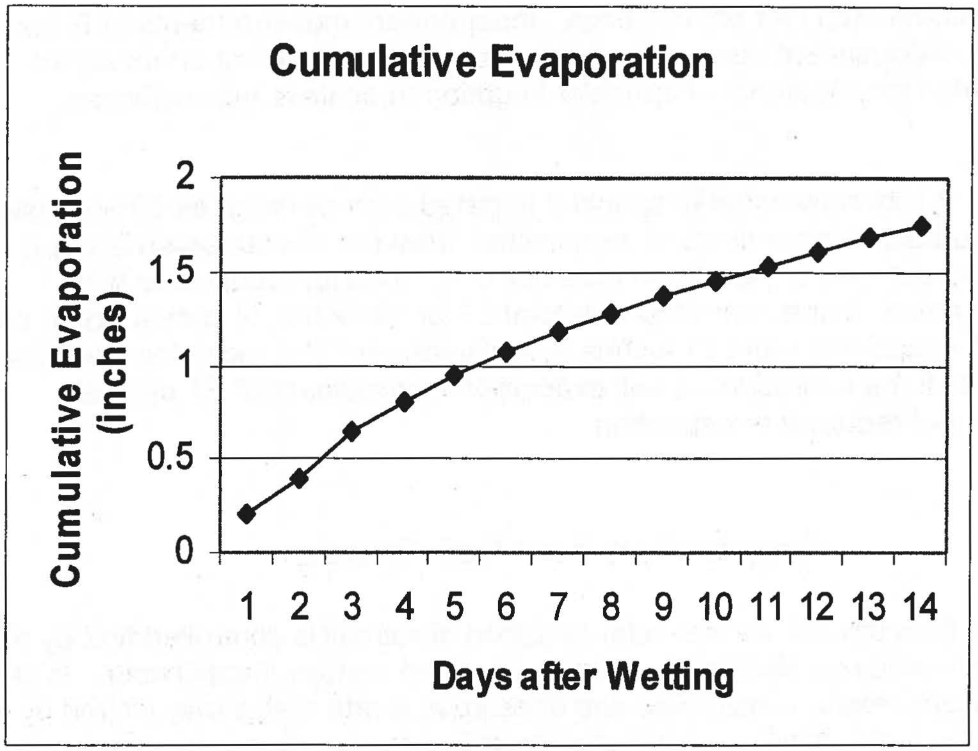

Fig.1. Soil limited evaporation after day 2 as described by E = C*t^-1/2.

Evaporation and Crop Residues

For many years, crop residues in dryland cropping systems have been credited for suppressing evaporation from soil surfaces. Evaporation research dates back into the 1930's when Russel reported on work with small canister type lysimeters. Stubble mulch tillage and Ecofallow have followed in the progression of innovations with tillage equipment, planting equipment, and herbicides to allow for crop residues to be left on the ground surface. These crop residue management practices along with crop rotations have increased grain production in the Central Plains. Water savings from soil evaporation suppression has been an essential element. In dryland management saving 2 inches of water during the fallow period from wheat harvest until planting corn the next spring was important because in meant an increase of 20-25 bushels in the corn crop. This difference came from the presence of standing wheat stubble during the fallow period versus bare ground.

The question is to what extent water savings could be realized from crop residue management in sprinkler irrigation. A research project was conducted during the mid 1980's to begin to address this question. Four canister type lysimeters were placed across the inter-row of sprinkler irrigated corn. The lysimeters were 6 inches in diameter and 8 inches deep and were filled by pressing the outer wall into the soil. The bottoms were sealed and the lysimeters were weighed daily to obtain daily evaporation from changes in daily weights. Increases in soil water over time due to elimination of root extraction in the lysimeters were compensated with a procedure of switching a duplicate set of lysimeters immediately after each irrigation or significant rainfall. When a set of lysimeters was not in field use it was dried and brought to field soil water content immediately before replacement in the field.

Half of the lysimeter treatments were bare and half were covered with flat wheat straw at the rate of 6000 pounds/acre or the equivalent to the straw produced from a 60 bu/acre wheat crop. The other variable was irrigation frequency. One treatment was dryland, receiving no irrigation. The next treatment was limited irrigation, receiving three irrigation events, one during vegetative growth, one during flowering, and one during grain filling. The last irrigation treatment was full irrigation with nine irrigation events. The first seven irrigations were delivered at week intervals and the last two and approximately two week intervals. The sprinkler irrigation system was a solid set equipped with low angle impact heads on a grid spacing of 40 ft X 40 ft. The corn population varied with the irrigation variable and was appropriate with the expected water application and yield goal for that treatment. The resulting leaf area, shading, and biomass followed accordingly.

The results of the field study conducted near North Platte Nebraska are in Figures 2 and 3. The soil for the study was a silt loam. The first striking result was in the dryland treatment. The unshaded bare and straw covered lysimeters nearly tracked each other for daily evaporation. There were only six rainfall events that measured over 0.4 in (10 mm) of precipitation. The pattern of cumulative evaporation for the bare dryland treatment indicates brief periods of energy limited evaporation. This indication is more subtle for the straw covered treatment. Even more interesting is that the straw mulched treatment has the same evaporation as the bare treatment for dryland management under the crop canopy. The straw mulch did not play an additional role in reducing the energy limited evaporation beyond the roll of the crop canopy.

For limited irrigation, three irrigation events were added, 2.0, 2.0, and 1.75 in. depths. The cumulative evaporation for bare soil, unshaded treatment showed the classic patterns of energy limited-soil limited evaporation. These patterns were suppressed in the other treatments indicating that the canopy and residue

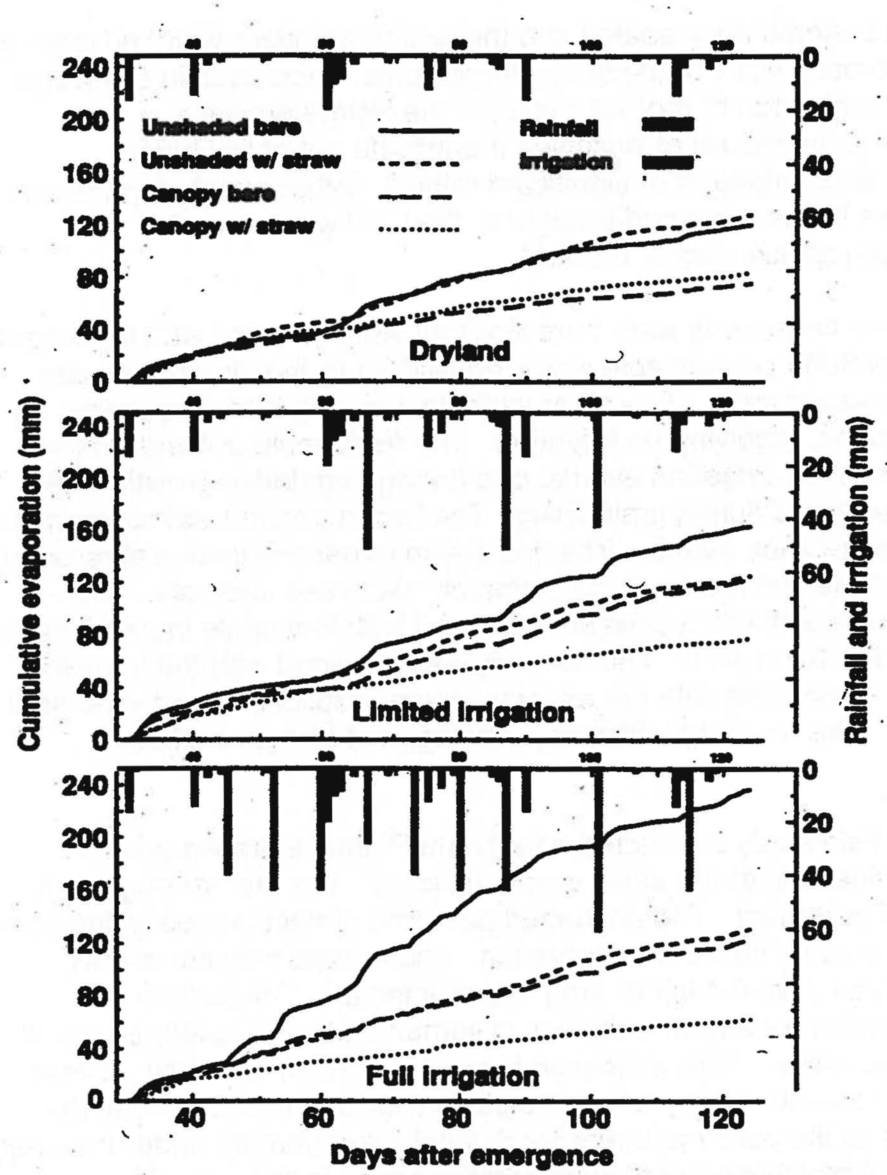

Fig. 2. Cumulative evaporation for dryland. limited irrigation, and full irrigation management. (Todd et, al., 1991)

prolonged the transition from energy limiting to soil limiting evaporation. During the last 40 days of the season the mulched unshaded treatment and bare treatment under the canopy closely tracked one another and ended with similar cumulative evaporation. The singular contribution of the straw mulch and crop canopy, each acting alone, were the same. However, in limited irrigation straw mulch added a benefit to the canopy effect that was not evident in dryland management.

Full irrigation included nine irrigation events, seven of which were at weekly intervals and two were at two-week intervals. The pattern of cumulative evaporation from the unshaded bare soil treatment indicated periods of both energy and soil limited evaporation. These patterns are more subtle early in the bare soil treatment under the crop canopy. The magnitude of unshaded bare soil

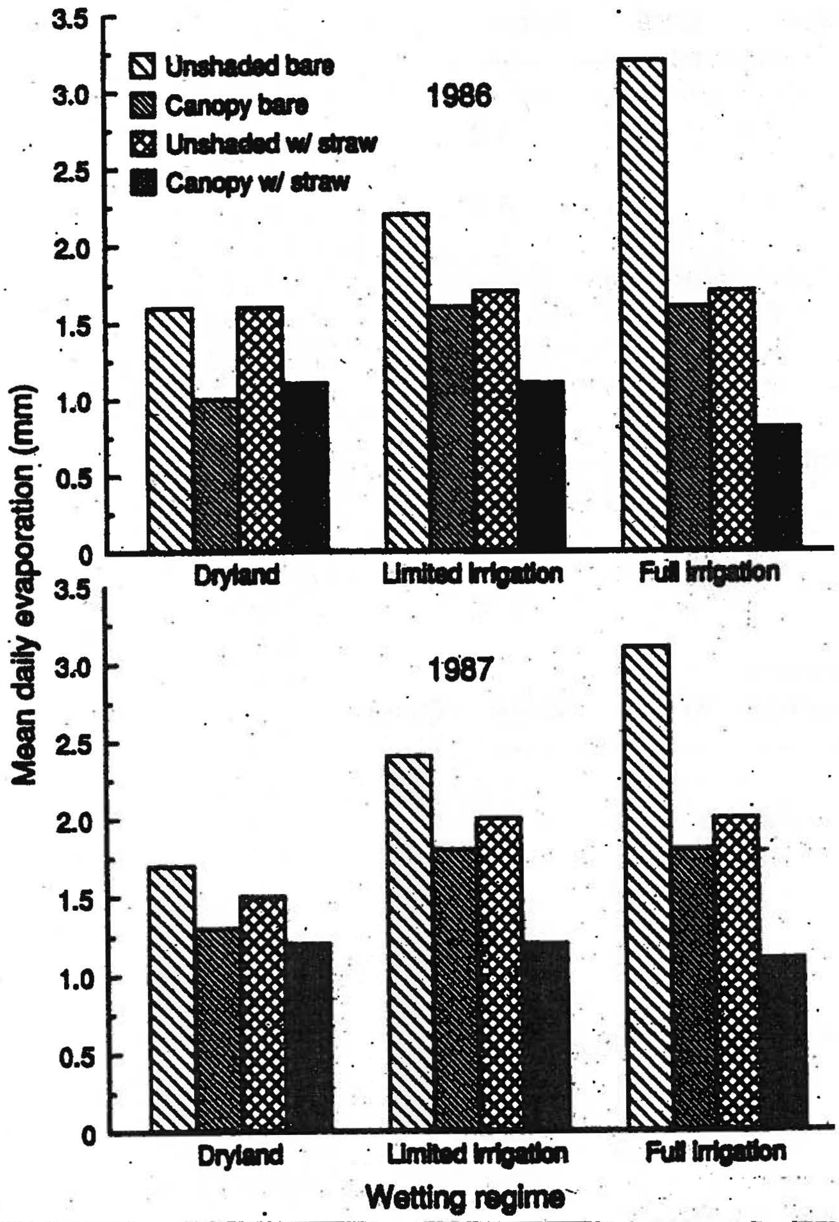

Fig. 3. Mean daily evaporation for dryland, limited irrigation, and full irrigation management. (Todd et. al., 1991)

evaporation is far greater in the fully irrigated treatment, but the unshaded mulched and bare soil evaporation under the canopy is similar to the limited values. These latter two treatments also track each other closely as they did in they limited management. The mulching effect was even greater in the fully irrigated management than the limited and dryland management. This effect started early and carried on throughout the growing season.

Table 1. Full growing season evaporation including irrigation and rainfall days.

Year	---Unshaded------ Bare	Straw	---Shaded------- Bare	Straw
	----------------in/season---------------			
	----------------Dryland------------------			
1986	7.6	7.6	4.7	5.2
1987	8.0	7.1	6.1	5.7
	--------------Limited Irrigation---------			
1986	10.4	8.5	7.6	5.2
1987	11.3	9.4	8.5	5.7
	-----------Full Irrigation----------------			
1986	15.1	8.5	7.6	3.8
1987	14.6	9.4	8.5	4.7

Table 2. Full Season Water Savings From Straw Cover.

Year	---Unshaded-----	----Shaded------
	---------------in/season-----------------	
	-------------------Dryland----------------	
1986	0.0	0.0
1987	0.9	0.5
	--------------Limited Irrigation---------	
1986	1.9	2.4
1987	1.9	2.8
	--------------Full Irrigation--------------	
1986	6.6	3.8
1987	5.2	3.8

Full Season Results

Cumulative evaporation results in figure 2 do not include days with occurrences of irrigation or rainfall. Measurements were not taken on these days. Data were collected from June 10 to September 13 in 1986 with 78, 75, and 75 days of collection from dryland, limited irrigation, and full irrigation, respectively. In 1987, data were collected from May 28 to August 20 with 65, 64, and 59 days of collection, for dryland, limited irrigation, and full irrigation, respectively.

To understand the possible full season implications of this study, the average daily evaporation rates were applied to the missing days of data. The results are shown in Table 1. These evaporation values may still be conservative since evaporation rates are highest immediately after wetting. The potential full season reduction in evaporation by the wheat straw cover is then shown in table 2.

Summary

No matter how efficient sprinkler irrigation applications become, the soil is left wet and subject to evaporation. Frequent irrigations and shading by the crop leave the soil surface in the state of energy limited evaporation for a large part of the growing season. Research has demonstrated that evaporation from the soil surface is a substantial portion of total consumptive use (ET). These measurements have been 30% of ET for E during the irrigation season for corn on sandy soil. It has also been demonstrated that crop residues, in this case wheat straw lying flat, can reduce in half the evaporation from soil even beneath an irrigated crop canopy. The goal is to reduce the energy reaching the evaporating surface.

We may be talking about seemingly small increments of water savings in the case of crop residues. The data presented here suggests the potential for a 2.5-3.5 inch savings in water due to the wheat straw during the growing season. Dryland research would suggest that stubble is worth at least 2 inches in water savings in the non growing season. In water short areas or areas where water allocations are below full irrigation, 5 inches of water translates into at least 60 bushels of corn. During 2002, many irrigators in the Central Plains could have used an extra 5 inches of water.

One of the challenges is to determine if other residues are as good as flat wheat straw in reducing evaporation. The flat wheat straw provided a compete mat, but it also retained moisture itself. Would other residues like untilled corn stalks or soybean stubble or standing wheat straw do as well or better?

References

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