EVAPORATION FROM SOIL AND VEGETATION

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SUMMARY

Some results of 28 years' measurements of moisture conservation and use in soil tanks and field plots are described. Most of the rainfall received in southwestern Saskatchewan is soon returned to the atmosphere by evaporation from bare soil or by transpiration from crops. Only 21 per cent of the precipitation is conserved in summerfallow during the 21-month summerfallow period. Wheat yield is determined largely by the moisture stored in the soil at seeding time and by the subsequent rainfall.

Rough estimates of evaporation from soil can be made under semi-arid conditions, such as in southwestern Saskatchewan, on the basis of predetermined evaporation curves giving the loss for different soil moisture conditions. Detailed data on capillary conductivity and diffusion coefficients are needed for computing moisture movement through soil to an evaporating surface.

Location and climate

The Soil Research Laboratory is located in southwestern Saskatchewan where deficient soil moisture limits crop growth almost every season. The average annual precipitation is only 14.9 inches of which 7.0 inches are received from May to July, inclusive, when the spring wheat crop is growing. The mean free-water evaporation (Canadian Experimental Farm Service tank, 4 feet in diameter and 2 feet deep set into the ground) for May to July is 18.5 inches, so that in most years the crop is subjected to severe moisture stress.

Field and tank methods of measuring evaporation

The conservation and use of soil moisture have been studied at Swift Current since 1922 using two methods. One method involves taking soil samples for moisture determination to the depth of root penetration (about 4 feet for wheat) at intervals during the season. The other method makes use of cylindrical tanks of soil, 15 inches in diameter and 5 feet deep, weighing about 600 pounds. The tanks are set into pits so that the soil surface is level with the surrounding ground. Crop rotations are grown in the tanks similar to those in the fields, and changes in soil moisture are obtained by weighing. Since moisture rarely penetrates below 4 feet in depth, the complete moisture economy can be studied by either the sampling or tank methods without allowing for drainage. Runoff, too, is rare in most seasons and usually can be neglected.

The rotations commonly followed in the plains area of Saskatchewan consist of wheat with summerfallow every second or third year. By measuring the moisture changes in both fallowed and cropped fields, and taking into account the precipitation received, the losses due to evaporation and transpiration can be computed.

Evaporation and conservation of moisture in summerfallow

Table 1, abstracted from a published paper, Staple and Lehane (1952), shows the precipitation and moisture stored during different parts of the 21-

month summerfallow period. About 33 per cent of the precipitation was conserved during the first fall and winter, and only 15 per cent during the last 12 months of summerfallow when the fields were bare. Losses during the May to October period were due largely to evaporation. Light showers did not

Table 1. Moisture conserved by substation soils during summerfallow periods.

	Stubble		Fallow		21-month total
	Aug. to Oct.	Nov. to April	May to Oct.	Nov. to April	
Mean precipitation (in.)	2.2	4.3	7.8	4.4	18.7
Mean conservation (in.)	0.8	1.4	1.0	0.7	4.0
Cons./prec. (per cent)	36	33	13	16	21

penetrate below the depth of cultivation and the moisture was soon lost by evaporation. On the other hand, the conservation from May to October may be as high as 35 per cent in seasons of ample, well-distributed rainfall. The mean conservation in stubble land at seeding time was 2.2 inches of water, and that in summerfallow 4.0 inches. The latter was only 21 per cent of the total precipitation received since harvest of the previous crop.

Relationship between evapotranspiration and wheat yield

Twenty-eight years' results from field plots (Staple and Lehane (1954c)) showed that, when moisture supplies were deficient, the yield of wheat varied almost linearly with the total evapotranspiration (moisture evaporated from the soil surface plus that transpired by the crop). About 5 inches of water were required before any grain was produced, and above 5 inches the yield increased about 4 bushels per acre for each additional inch of water used. The relationship was slightly curvilinear with the yield per inch of water increasing gradually with total moisture use. The yield must reach a maximum at high values of evapotranspiration when moisture is no longer a limiting factor in the growth of the crop. Long-time averages showed that stored moisture and rainfall received during the crop season (seasonal rainfall) had almost equal influence on the ultimate yield.

Correlation between wheat yield and free-water evaporation, air temperature and sunshine

The partial correlation coefficient obtained between wheat yield and free-water evaporation when the effects of differences in stored moisture and seasonal rainfall were removed was negative and very small. Wheat yield was influenced significantly by evaporation, however, when the latter was an independent variable with evapotranspiration M and M^2 in a curvilinear regression equation. The mean air temperature was closely related to free-water evaporation and could be used in place of evaporation for computing yield in the quadratic equation with M and M^2. Wheat yields were not significantly correlated with hours of sunshine.

An interesting feature of these results, based on 28 years' measurements, was that the negative correlation obtained between free-water evaporation and stored moisture used by the wheat crop was just short of significance for tank crops and significant at the 1 per cent level for crops grown on plots.

Soil and weather conditions influencing evapotranspiration

Partial correlation coefficients obtained between evapotranspiration by wheat grown in tanks and free-water evaporation, rainfall and stored moisture for six 15-day periods, during growth of the crop, showed that evapotranspiration was significantly and positively correlated with free-water evaporation only during the first month of growth. Later in the season, when crops were under moisture stress, the partial correlations with evaporation were small and tended to be negative. High partial correlations were obtained between evapotranspiration and the stored moisture in the soil for each of the 15-day periods.

Effect of soil texture on evapotranspiration and wheat yield

It was shown by Lehane and Staple (1953) that in normal seasons most soils in southern Saskatchewan were able to hold, within the depth of root penetration, all the moisture reaching the subsoil. It follows that the higher yields obtained on soils of fine texture must be due partly to the higher tension with which the soil moisture is held. About 50 per cent of the maximum moisture available to a crop in heavy clay at seeding time is held with a tension greater than 8 atmospheres, whereas only 16 per cent of the maximum moisture in a clay loam is held with such a stress. Presumably the higher tension in clays results in less early vegetative growth and consequent waste of moisture that is sorely needed later in the season. Some differences in moisture efficiency have been observed between crops grown on a group of loam soils representing a fairly narrow range of textures (Staple and Lehane (1954b)).

Estimating evaporation from soil

Hopkins (1940) used some of the data obtained in tank experiments (Soil Research Laboratory (1949)) to show the effect of rainfall distribution on moisture conservation. The amount of moisture stored depended on the total rainfall received and its distribution both during and before the period of observation.

Numerous laboratory measurements of evaporation were made at Swift Current to find the influence of different amounts of initial soil moisture and simulated rainfall on evaporation from soil. A method of estimating evaporation and conservation in summerfallow, based on such measurements, was described by Staple and Lehane (1944). The method gave satisfactory estimates of the moisture conserved in tanks and field plots. Because of over-simplifications, however, the method was applicable only under weather conditions such as normally experienced at Swift Current, i.e., where individual storms of over an inch of rainfall were rare, and the subsoil moisture content was below field capacity. A more fundamental approach was required to estimate evaporation for a wide range of meteorological conditions.

Capillary conductivity and evaporation from soil

Evaporation from soil is controlled both by soil conditions that determine the rate of movement of moisture upward to the surface, and by meteorological conditions that determine the rate of loss to the atmosphere. Computation of evaporation must, therefore, be a stepwise process involving the calculation, in short time intervals, of both the changing moisture profiles in the drying soil and the resulting evaporation at the surface. Special information about capillary conductivity and diffusion coefficients is necessary before moisture movement through soil can be computed. Usually these data are not available, and they are difficult to measure.

Mean values of capillary conductivity coefficients have been obtained by sampling soil columns at short time intervals during drainage or evaporation (STAPLE and LEHANE (1954a)). Thus far the conductivity coefficients for a clay loam seem to increase exponentially with the bulk density of the soil and the volume of water contained in the pore spaces. A paper containing recent work on this subject has been prepared for submission to the *Canadian Journal of Agricultural Science.*

There is need for improved methods of determining conductivity coefficients, and for using them to compute moisture movement in unsaturated soils. Numerical and graphical methods have been used for the latter purpose but both are very time-consuming. The possible effects of temperature gradients and hysteresis on capillary and vapour movement near the surface are not known. These might be of special importance in evaporation from a bare soil, exposed as it is to intermittent sunshine and rain.

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