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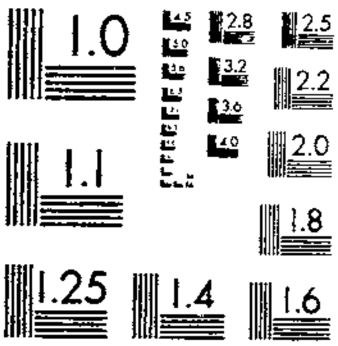

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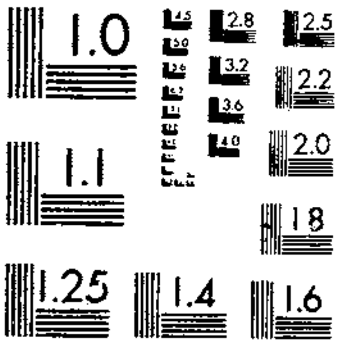

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EVALUATION of AGRICULTURAL HYDROLOGY by Monolith Lysimeters

1944–55

By

L. L. Harrold, Project Supervisor

and

F. R. Dreibelbis, Soil Scientist

Soil and Water Conservation Research Division

Agricultural Research Service

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Washington, D. C. **Issued August 1958**

EVALUATION OF AGRICULTURAL HYDROLOGY BY MONOLITH LYSIMETERS 1944-55

By L. L. Harrold, project supervisor, and F. R. Dreibelbis, soil scientist, Soil and Water Conservation Research Division, Agricultural Research Service [1]

SUMMARY

This bulletin is a progress report on the lysimeter investigations carried on at the Soil and Water Conservation Research Station near Coshocton, Ohio, from 1944 through 1955. Summaries of percolation data are presented for the period 1938–55.

The hydrologic data were obtained from 11 monolith lysimeters, each 0.002 acre in area and 8 feet deep, 3 of which were weighed automatically every 10 minutes. The features of the installations, some of which are unique, are described briefly. Unlike many lysimeters, percolation from the soil into cracks and crevices of the rock at the 5-foot depth takes place naturally without supplying extra tension. Records of this percolation water collected at the 8-foot depth, along with records of precipitation and runoff, are presented in tables and graphs for each lysimeter. Weight records provided data for determination of moisture storage changes in the soil monolith. Daily gains in weight not associated with periods of precipitation were designated as condensation and absorption. Evapotranspiration values were derived from the weight records in like manner during periods of loss.

The amount of moisture condensed and absorbed was fairly large, ranging from 6 to 10 inches of water annually. This is in addition to precipitation. Although this moisture, or dew, may be entirely evaporated in the morning hours, its value in conserving soil-moisture supplies is notable. One month when only 0.55 inch of rain fell, 1.39 inches of dew was an important factor in reducing drought damage. The highest daily value of condensation-absorption was 0.08 inch. The amount of dew was greater on dry unirrigated soil than on moist irrigated soil. The period of most rapid accumulation of dew was generally from about 4 to 10 p. m.

Soil-moisture depletion by evapotranspiration was greatest in May,

[1] The work on this experimental watershed project was done at the Soil and Water Conservation Research Station near Coshocton, Ohio, by the Soil and Water Conservation Research Division, Agricultural Research Service (formerly the Research Division of the Soil Conservation Service) in cooperation with the Ohio Agricultural Experiment Station. The data were collected by the project staff. Much of the work of operating the lysimeters and tabulating the basic data were performed by William W. Bentz and Robert E. Youker. J. H. Wilson of the Ohio Agricultural Experiment Station, Wooster, Ohio, assisted in the chemical analyses of percolation water.

June, July, and August. Stage of crop growth, that is, development of leaf area and maturity, as well as depth of root penetration and available soil moisture affected evapotranspiration values. With normal precipitation, evapotranspiration values averaged from about 80 to 90 percent of the annual supply. In years of deficient precipitation, evapotranspiration used about 96 percent of the supply.

The correct value of net moisture depletion is "evapotranspiration minus condensation-absorption," or ET—CA. These consumptive-use values varied from season to season as affected by the climate, crop, and supply of soil moisture. The highest rates of consumptive use for cornland were in July and August. Those for grassland were in May and June. Irrigation tended to prolong the high water-use rate for grass into late July and August and for corn until late August.

The amount of water used to produce a pound of corn crop ranged from 273 to 586 pounds. The most efficient use of water occurred with irrigation and the highest crop yield (196 bushels of corn per acre). Actually, the least amount of water—17 to 19 inches—was used in producing the lowest yields but represented the greatest unit amount of water per unit of crop. A total of 23.5 inches of water was used in producing the highest yield of corn.

Graphs of accumulated daily consumptive use of water reflect various farming operations such as: (1) Reduction of water use after spading sod for corn planting, (2) increase in water use as leaf area of corn plant develops, (3) reduction of water use after cutting and removal of hay, (4) increase in water use as meadow crop leaf area develops, and (5) increase in water use after irrigation in August.

Graphs of daily soil moisture for each year, 1944–55, inclusive, show the fluctuation of moisture in 40 inches of soil for lysimeters in crops and in continuous grass-legume cover and for different soils. Periods of saturation, depletion, minimum moisture, and accretion are readily apparent. The effect of irrigation and the influence of vegetal cover on soil moisture are considerable. During May and June, one year, about 5 more inches of water was extracted from the 40-inch soil profile on an alfalfa-bromegrass sod than on cornland.

Precipitation as measured by the weighing lysimeters differed from that caught in the Fergusson recording rain gage. The average annual precipitation for the period 1945–55 was 4.38 inches less for the Fergusson recording gage than for the lysimeter. Much of the variation in years of widely-divergent precipitation values by the two methods is accounted for in snowfall. The scatter of points above and below the line of equal values on a graphical comparison indicates no consistent year-after-year deviation in the daily rainstorm values.

Lysimeter evapotranspiration is compared with pan evaporation and atmometer water loss for several years and for several crops. In some periods evapotranspiration and pan-evaporation rates were about equal. In other periods evapotranspiration from cornland exceeded pan evaporation by as much as 40 percent for nearly 2 months. Evapotranspiration also exceeded water loss from the white atmometer bulbs, but by lesser amounts.

Monthly and annual values of percolation from each lysimeter are summarized for different soil types. Peak rates of percolation coincided with periods of high soil moisture. Percolation for the first 4 months of the calendar year comprised 80 percent of the annual amount for lysimeter battery Y102 and 65 percent for battery Y101. In the former, parent material is shale and in the latter it is sandstone. The greatest annual total percolation came from battery Y101 (sandstone material); the maximum in 1 year was 26.37 inches in 1950 from lysimeter Y101C (bluegrass). The minimum was zero in 1954 from Y101D (in alfalfa-bromegrass).

Leaching of plant nutrients through the soil profile is evaluated by chemical analysis of percolation water from each lysimeter. Annual nutrient losses vary considerably. The variation is caused by large differences in annual percolation and by applications of fertilizer. Data for both are presented. Nitrate losses ranged from 0.03 to 14.85 pounds per acre per year.

A brief review of literature on lysimeter investigations which has appeared during the period 1939–55 is included.

BACKGROUND OF THE STUDY

Agricultural hydrology in recent years has become a subject of major interest in many fields of activity. From the large-scale governmental flood-control, land-reclamation, and irrigation projects down to the individual farm operation, consideration of water movement across, into, and through soils is becoming increasingly important. Industries, municipalities, and agriculture the country over are conscious of the need for water conservation. Thus, much attention is being given to the need for better control of water and reduction of water waste. Perhaps the first place to begin control is the land surface where the raindrops fall.

A knowledge of water movement over the land surface, movement into and through the soil, condensation and absorption of water, evaporation, and use of water by crops is necessary for a comprehensive approach to water control. Soil moisture is never constant; it is either increasing or decreasing. It may be reduced through crop use, evaporation, or percolation downward to ground-water reservoirs. Precipitation absorbed by the soil replenishes soil-water supplies. These processes result in a continuously changing soil-water supply. Even frozen soil may vary in soil-moisture content from day to day.

The lysimeter studies at Coshocton were planned to obtain measurements of the various water-cycle factors under different seasonal, vegetal, and soil-type conditions. This report, based on about 12 years of data, summarizes and discusses the results of these studies through 1955. In some instances, summaries extend back to 1938. Analyses of these lysimeter data will serve as a teaching aid in colleges, a reference in many soil-and-water management programs, along with watershed development, and as a source of facts for irrigation guides in many areas.

Throughout the entire period of record there were many times when soil moisture was sufficient to meet crop needs. For these, the evapotranspiration values were the maximum for the climatic experience. Occasionally soil moisture was so deficient that evapotranspiration values were less than maximum. For the years prior to 1953 soil moisture was supplied by natural phenomena—rain, snow, and dew. In 1953, 1954, and 1955 two lysimeters were irrigated to provide ample moisture for crop needs.

Precipitation for the period 1944–55 averaged 3.70 inches less than the long-term normal for this area. Only 2 of the 12 years recorded more than normal precipitation, with 1950 being excessive by 7.25 inches. The most critical moisture-deficient period was 1953–55. Annual deficits of 11.69, 8.22, and 9.44 inches totaled 29.35 inches for these 3 years. Precipitation in 1953 was 28.34 inches. Only once before was there a year of less precipitation. That was in 1930 when 22.03 inches was recorded in Coshocton.

Evaluation of agricultural hydrology presented in this bulletin reflects the variation in climate for the period. The reader is encouraged to examine the results of these lysimeter studies in the light of the natural and artificial supply of moisture.

Lysimeters in general may be defined as structures containing a mass of soil, and so designed as to permit the measurement of water draining through the soil. Three general types used in the past are as follows:

1. *The filled-in type*—where the containing unit with vertical walls, open top, and perforated bottom is filled with soil removed from its original location. Usually this soil is screened and mixed to make it uniform. Since the natural permeability characteristics of the original soil profile cannot be retained in this type of lysimeter, the soil-moisture relationships do not represent natural conditions.

2. *The Ebermayer type*—where a shallow pan or funnel is inserted at desired depths under undisturbed soil horizons. Since there are no side walls the soil of the lysimeter is not separated from the adjoining soil. The pan funnels the percolation water to a measuring tank. This type allows unrestricted lateral movement of soil water and surface runoff.

3. *The monolith or undisturbed-soil-block type*—where a casing of vertical walls is built around a block of soil *in situ*. A perforated pan is inserted beneath the soil block to collect percolation water.

There has been much criticism of the different lysimeters. Some lysimeters do not permit runoff, all the precipitation being held on the ground surface until it is absorbed. Others permit runoff but do not measure it. All have artificial bottoms that do not allow capillary movement of water upwards. In many lysimeters the floor of the metal collector interrupts the natural drainage and causes unnatural wet layers at the bottom. Some permit the lateral movement of soil water, others restrict it.

The Coshocton lysimeters were specifically planned as watercycle instruments. Therefore, detailed attention in the design was given to soil-water relationships that would affect their performance. Every effort was made to eliminate the objectionable features of previous lysimeter installations.

The Coshocton lysimeters differ from most installations of this nature in several respects (*70*).[2] Some of the more important features of their construction and operation are as follows:

1. Side walls prevent lateral movement of water.

2. A large rectangular surface area, 6.22 x 14 feet, permits cropping with a field spacing of 4 corn rows, 42 inches apart.

3. The large surface area minimizes the artificial border effect along sides of casing.

4. Four side-wall baffles, inserted on each of the four sides after the lysimeter casing had been sunk, reduce water seepage down these un-

[2] Italic numbers in parentheses refer to Literature Cited, p. 147.

natural planes. These baffles function like piston rings.

5. Preserving the natural soil profile of topsoil, subsoil, and geologic parent material provides an opportunity to observe soil-water relations approximating natural conditions.

6. Parent-material rock (shale or sandstone) about 3 feet thick at the bottom provides a natural means of transmitting percolation water from the overlying soils to free gravity water draining off into observation tanks. Fissures and crevices in the rock layer also naturally break the capillary columns through which ground water might otherwise rise. This rock layer permits the insertion of percolation pans and the removal of the underlying rock without interfering with the normal downward or upward movement of the water.

7. Multiple percolation-pan bottoms in the lysimeters permit observation of percolation at 8 sections of the 14-foot length.

8. Automatic weighing devices, developed expressly for this study, record weight changes in the 65-ton soil mass to a 5-pound accuracy. This is equivalent to about 0.01 inch of water over the lysimeter surface area. From these weight records it was possible to derive data on precipitation, condensation-absorption of water, and evapotranspiration for various periods of the day.

A more complete description of these features along with the construction and installation history is given further on.

REVIEW OF RECENT LITERATURE

The literature reviewed here covers, in general, the period from 1939 to 1955. An extensive review of literature by Kohnke et al. (*70*) covered two and a half centuries of research in lysimetry up to 1939. No repetition of this excellent review is made.

The purpose of most lysimeter investigations has been to study problems in hydrology, soil fertility, or both. A few studies, such as those reported by Wallihan (*132*) and Colman (*25*), were concerned primarily with lysimeter design. Wallihan pointed out that with shallow lysimeters 30 inches deep and 12 inches in diameter it was necessary to use a tension of 10 cms. mercury to provide drainage corresponding to the normal drainage of the soil. Colman used various drainage tensions to determine water outflow under each tension. It appears from these data that some tension is needed to simulate natural soil drainage in shallow lysimeters where true soil rests directly above the percolation pans. The Coshocton lysimeters were designed to overcome this objection by including in the lysimeter soil profile about 3 feet of bedrock that would rest directly above the percolation pans.

Studies on moisture condition in lysimeters by the use of tensiometers were made by Richards et al. (*104*). Among recent hydrologic studies made with lysimeters in this country, the most noteworthy are those of Martin and Rich (*89*) in Arizona, Colman and Hamilton (*26*) and Hamilton (*50*) in California, Stauffer (*116*) in Illinois, and Kilmer et al. (*69*) in Wisconsin. The last two investigations also included studies on nutrient losses in the percolate.

Lysimeter studies of the nitrogen balance in soils have been made for a long time by numerous investigators both in this country and abroad. Examples of such studies made since 1939 include those of Bizzell (*9*, *10*) in New York, Chapman et al. (*24*) in California, Karraker et al. (*68*) in Kentucky, and MacIntire et al. (*86*) in Tennessee. Stauffer and Rust (*117*) have studied leaching losses, runoff, and percolate from eight Illinois soils. In addition to evaluating nitrogen losses from these soils, they included in their study a determination of calcium, magnesium, potassium, sodium, sulfur, and silica. They also made a statistical interpretation of the data. They conclude that their study indicated that leaching losses from soils were lower than was previously believed.

The Tennessee station has made numerous studies on leaching of various chemicals for a long time. The investigations reported since 1939 were made by MacIntire or Shaw and their coworkers (*27*, *75-86*, *92*, *93*, *111*.)

Chapman and his coworkers in California have reported results of a number of lysimeter investigations (*12*, *22*, *23*) in which they studied the balance of plant nutrients and salts in irrigated soils. They reported gains, losses, and balance data for calcium, magnesium, potassium, sodium, phosphorus, sulfur, chlorine, bicarbonate, and nitrogen for a 15-year period. Their data indicate that about 8 percent of the total rainfall (about 11.5 inches annually) plus irrigation water applied would have to percolate through the soil to prevent salt accumulation.

More recently Allison and Reeve (*1*) have used lysimeters in California to study plant response to salinity as influenced by water-table conditions. For water-table control, each lysimeter was provided with a float-valve type of head control device, which was arranged to move up and down on a control panel. The movable float-valves were connected in the line between the water reservoirs and the drainage pipes leading from the bottom of the lysimeters. The desired water-table levels were established by raising or lowering the float-valves on the control panels.

A number of lysimeter investigations in forest cover are being carried on by the United States Forest Service at San Dimas, Calif. (*26*), Tucson, Ariz. (*89*), and elsewhere. The extensive work by Lunt (*74*) with lysimeters on forest cover in Connecticut was concerned primarily with the composition of the percolate. Other studies reported since 1939 on the composition of the percolate include those of Bizzell (*9*, *10*) in New York, Volk and Bell (*130*, *131*) and Volk (*128*, *129*) in Florida, Roller and Bowen (*105*) in South Carolina, Plice (*102*) in Oklahoma, Smith (*114*) in Arizona, and Kardos (*67*) in Washington. Filled-in lysimeters were used in all these investigations except that of Kardos, who used the Ebermayer type. Neller and Forsee (*95*) of Florida report the use of a lysimeter for organic soils. Because of the high water table in organic soils, a special filled-in type of lysimeter was used in which the lysimeter soil surface was 4 feet above that of the adjacent fields. Joffe (*63*, *64*) in New Jersey reports a study of the movement of cations and anions through the soil profile by use of the Ebermayer type of lysimeter. Lowdermilk and Sundling (*73*) have used lysimeters in their study of the formation and significance of erosion pavements.

Among the lysimeter investigations reported outside the United States are those of Bastisse and his coworkers (*5*, *7*, *8*, *30*, *31*) in France; Cavanillas et al. (*16*, *21*) in Spain; Deij (*28*, *29*), Maschhaupt (*90*, *91*), and Visser (*127*) in Holland; Geering (*48*) in Switzerland;

Drover and Barrett-Lennard (*43*), and Annett (*2*) in Australia; Roseau (*106*, *107*, *108*) in Algeria; Haouet (*51*) in Tunis; Sundara Rao et al. (*118*) in India; Winnik (*133*) in Israel; Bryssine (*14*) in Morocco; Shawarbi (*112*) in Egypt; and Smith (*113*) and Van't Woudt (*125*, *126*) in New Zealand.

Some of the hydrologic studies made by use of lysimeters are those of Aslyng and Kristensen (*4*) on Danish soils; Boschi (*11*), who worked on auxiliary irrigation in lysimeters; Van Doorn (*33*) on hydrologic observation with lysimeters in Holland; Hesse (*60*), who measured transpiration of plants by small lysimeters; Makkink (*87*, *88*), who determined evapotranspiration from grassland; Hooghoudt (*61*) on the use of lysimeters for ground-water studies; Van Nievelt (*96*) on drinking water supplies; Pfaff and Friedrich (*99–101*) on water balances of soils; Theron (*120*) in South Africa on percolation under fallow and crop conditions; and Kalweit (*66*), who presented data on the percentage of annual evapotranspiration for each month with different kinds of plant cover. Of particular interest is the work of Turc (*121*, *122*), who studied the moisture balance in cropped and uncropped soils in lysimeters in various parts of the world. A list of 100 references was given (*122*).

Other investigations reported outside the United States are those by Arrhenius (*3*), Benjaminsen (*8*), Bruin (*13*), Carrente et al. (*15*), de Gruyter (*49*), Dimo (*32*), Friedrich (*44–46*), Galvez and Bueno (*47*), Howell (*62*), Jolivet and Helias (*65*), Kupper (*71*), Lee (*72*), Natermann (*94*), Odelien and Uhlen (*97*), Odelien and Vidme (*98*), Scharrer and Kühn (*109*), Scharrer, Kühn, and Lütmer (*110*), and Suomi et al. (*119*).

Data obtained from the Coshocton lysimeters have been presented in hydrologic data bulletins (*123*, *124*), and in the papers of Dreibelbis and Post (*41*, *42*), Post and Dreibelbis (*105*), Harrold and Dreibelbis (*57*, *58*), Harrold (*52*, *56*), Dreibelbis and Harrold (*39*), Dreibelbis (*35–37*), Dreibelbis and Bender (*38*), and Harrold and Yoder (*59*). These papers were concerned primarily with problems in hydrology. In the work of Stackhouse and Youker (*115*) the accuracy of Fiberglas-gypsum blocks was evaluated by the weighing lysimeter. The papers by Dreibelbis (*34*) and by Dreibelbis and McGuinness (*40*) reported on a study of the plant nutrient losses in lysimeter percolates. In the latter paper, a statistical interpretation was made of the data obtained through 1955.

DESCRIPTION AND HISTORY OF INSTALLATIONS

The research plan developed in 1935 for the Soil and Water Conservation Research Station at Coshocton, Ohio, provided for a study of all the factors affecting the disposal of precipitation as part of a comprehensive study designed to uncover the basic laws governing agricultural hydrology. Precipitation and surface-runoff measurements from agricultural fields were to provide data basic to the determination of the rates and amounts of water absorbed by the soil. In order to evaluate the extent to which land-use practices affect water absorption and conservation of water and soil, and to obtain complete data on all phases of the precipitation-disposal system, the studies also included measurements of the loss of soil water by evapotranspiration and percolation below the root zone. For this purpose, the Soil Conservation Service built at Coshocton, in the period 1937–40, a number of monolith lysimeters equipped with self-recording weighing mechanisms—the first in the history of lysimeter investigations.

Since a major purpose of the lysimeters was to provide data needed in the analysis and interpretation of watershed data, the lysimeters were established in areas representative of different watershed conditions. To avoid disturbing the natural conditions of the watershed areas unduly, the lysimeters were installed on sites adjacent to the watersheds where the slope, aspect, and soil profile were typical of the watershed. Because of the high estimated cost of the desirable type of lysimeter, the lysimeter installations were limited to three sites as follows:

1. Permanent grassland on steep (23.2 percent), well-drained soil (Muskingum silt loam); site Y101.
2. Rotation cropland on rolling (12.9 percent), well-drained soil (Muskingum silt loam); site Y102.
3. Rotation cropland on rolling (6.0 percent), slowly permeable soil (Keene silt loam); site Y103.

The location of the lysimeter sites and other hydrologic installations is shown on a map of the experiment station (fig. 1). Three lysimeters were constructed at each site. This unit at each site is referred to as a "lysimeter battery." Some of the more important physical and agronomic features of the watersheds are shown in table 1.

All lysimeters in the same battery were to be operated the same so as to disclose any discrepancies that might result from differences inherent in the soil blocks. A fourth lysimeter was subsequently added to the batteries at Y101 and Y103. At Y101 the additional lysimeter provided a means for measuring the hydrologic effect of different grass mixtures. At Y103 the additional lysimeter made it possible to operate two units according to a conservation plan and to keep two as a check. One lysimeter in each of the three batteries was equipped with an automatic weight recording mechanism.

LYSIMETER SITES

The physiography and soils at the three lysimeter sites vary in important respects.

Physiographic characteristics (all elevations are for height above mean sea level):

Y101.—Land slope, 23.2 percent; aspect east; elevation of lysimeter surface about 1,185 feet; elevation of crown of hill above lysimeter site, 1,245 feet.

Y102.—Land slope, 12.9 percent; aspect east; elevation of lysimeter surface, about 1,185 feet; elevation of crown of hill above lysimeter site, 1,200 feet.

Y103.—Land slope, 6.0 percent; aspect south; elevation of lysimeter surface, about 1,128 feet; elevation of crown of hill above lysimeter site, 1,130 feet.

Soil types:

Y101, Muskingum silt loam (sandstone origin).—This soil type belongs to the Gray-Brown Podzolic group and is residual in origin. The entire profile is permeable and has good drainage. A description of the profile near lysimeter Y101 follows:

Depth (Inches)	
0–8	Dark brown silt loam with texture approaching a loam.
8–16	Brown to yellowish-brown silt loam to loam with some sandstone fragments.
16–33	Brown to yellowish-brown loam with sandstone fragments.
33–51	F[illegible] omposed sandstone with sandstone fragments.
51–96	[illegible]ghtly decomposed sandstone rock with few sandstone fragments.

Y102, Muskingum silt loam (shale origin).—This soil type belongs to the Gray-Brown Podzolic group, is residual in origin, and occurs extensively in the North Appalachian Region. There is

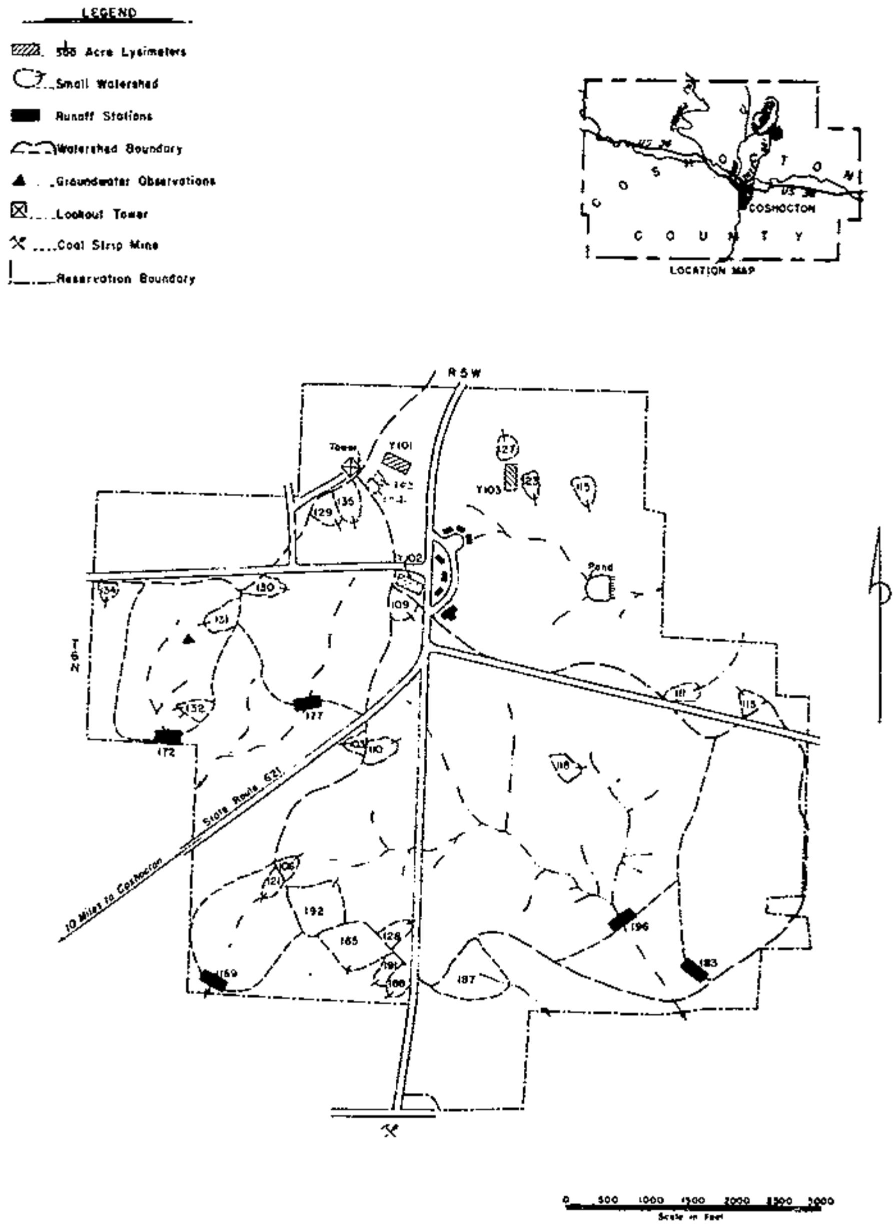

FIGURE 1.—Map of experimental area showing location of lysimeter batteries and other equipment used in obtaining hydrologic data.

TABLE 1.—*Physiographic and agronomic features of watersheds on Government land used for hydrologic observations, Coshocton, Ohio*

Watershed No.[1]	Land use	Drainage area	Cover and rotation [2]	Practice [3]	Predominant soil type
		Acres			
131	Woods	2.21	Hardwoods	Conservation	Muskingum loam.
132	do	.59	do	do	Keene silt loam.
134	Reforested	.92	Pines	do	Muskingum silt loam.
130	Meadow	1.63	Alfalfa-timothy	do	Do.
129	Pasture	2.71	Alfalfa, ladino clover, bromegrass.	do	Do.
135	do	2.69	Poverty grass, briars.	Poor	Do.
102	do	1.26	Alfalfa, ladino clover, bromegrass.	Conservation	Do.
104	do	1.33	Bluegrass	do	Do.
109	Cultivated	1.69	C-W-M-M	do	Do.
115	do	1.61	do	Poor	Muskingum and Keene silt loam.
123	do	1.37	do	Conservation	Keene silt loam.
127	do	1.65	do	Mulch	Do.
103	do	.65	M-C-W-M	Conservation	Do.
110	do	1.27	do	Poor	Do.
128	do	2.68	do	Mulch	Muskingum loam.
111	do	1.18	M-M-C-W	do	Coshocton silt loam.
113	do	1.45	do	Conservation	Do.
118	do	1.96	do	Poor	Do.
106	do	1.56	W-M-M-C	do	Muskingum loam.
121	do	1.42	do	Conservation	Do.
188	do	2.05	do	Mulch	Muskingum silt loam.
192	do	7.59	M-C-W-M	Poor	Do.
185	do	7.40	Contour strip cropped.	Conservation	Do.
187	do	7.20	do	do	Keene silt loam.
169	Mixed	29.0	Mixed	do	Mixed.
172	Woods	43.6	Woods	do	Do.
177	Mixed	75.6	Mixed	do	Do.
183	do	74.2	do	Poor	Do.
196	do	303	do	do	Do.

[1] See fig. 1 for location in relation to lysimeter batteries Y101, Y102, and Y103.
[2] C—corn, W—wheat, M—meadow.
[3] "Conservation" practice means contour cultivation, high fertility level, and soils with pH of 7.0. "Poor" practice means straight rows, low fertility level, and soils with pH of 5.4.

no mottling in the profile and the drainage is good. A description of the profile near lysimeter Y102 follows:

Depth (Inches)	
0–7	Brown to yellowish-brown silt loam (plow layer).
7–14	Yellowish-brown silt loam, slightly heavier than surface soil; occasional shale fragments.
17–24	Yellowish-brown silt loam to fine sandy loam containing many sandy shale fragments.
24–39	Partly decomposed shale in various stages of decomposition; fragments increasing in size with depth.
39–60	Layer of shale in various stages of decomposition containing layers of ferruginous material; mostly undecomposed.
60–96	Bedrock consisting of undecomposed shale with some shale in first stages of decomposition.

Y103, Keene silt loam.—This soil type occurs extensively in the vicinity of the experiment station. It belongs to the same group of upland soils as the Muskingum series but differs distinctly from the latter in its hydrologic characteristics. The subsoil is characterized by a heavy, relatively impermeable, silty clay whereas the Muskingum silt loam subsoil is a rather pervious loam or silt loam. A description of the profile near lysimeter Y103 follows:

Depth (Inches)	
0–7	Gray-brown silt loam (plow layer).
7–15	Yellowish-brown silt loam; unmottled; slightly heavier than surface soil.
15–27	Yellowish-brown silt loam to silty clay loam; slightly mottled with gray.
27–41	Mottled gray, yellowish-brown and rust-brown heavy silty clay, gray color predominating.
41–76	Gray heavy silty clay containing shale fragments.
76–96	Partially decomposed clay shale to decomposed clay shale.

The mechanical analysis of these soils is given in table 2, and the chemical analysis of typical soil profiles adjacent to the lysimeters is given in table 3. These analyses, based on samples taken at the time the lysimeter casings were being sunk, include a complete profile to a depth of 8 feet.

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LYSIMETER CONSTRUCTION

A careful study of the literature and an inspection of conventional types of lysimeters revealed that none were adequate for the purposes of this study. The Coshocton lysimeters were a distinct departure from previous installations in details of design and in the broad scope of information obtainable.

The plan and typical cross section of a battery of lysimeters appear in figure 2. The three lysimeters of each battery were constructed close together in order to keep the length of the shelter tunnels to a minimum. A space of 6 feet between adjoining soil blocks was required to permit enclosing each block without disturbing any of the others.

The soil block was enclosed by building a reinforced concrete casing with vertical walls in location on the ground surface and then lowering it by removing the soil from beneath the bottom edge. The lower edge of the casing was beveled, and a steel cutting edge was attached to facilitate lowering. The casing was 8 feet high. The inside dimensions were a width of 6.22 feet across the land slope and a length of 14 feet, to provide an enclosed area of 0.002 acre. The top and bottom edges of the walls were parallel to the ground surface. To prevent seepage of water through the casing, the inside walls were first coated with creosote, which penetrated into the pores of the concrete, and then covered with hot asphalt.

The casing was constructed with 4 horizontal grooves 1½ inches deep in the interior face of each of the 4 walls. After the casing was lowered to enclose the 8-foot undisturbed soil monolith, steel strips 3 inches wide were driven into these grooves, with 1½ inches of each strip protruding into the soil monolith. In effect, the four strips act as piston rings in a cylinder of an

TABLE 2.—*Mechanical analysis of soil profiles adjacent to lysimeters*[1]

LYSIMETER Y101, MUSKINGUM SILT LOAM (SANDSTONE)

Soil depth represented (inches)	Description	Analysis of total materials		Analysis of particles <2 mm.		
		>2 mm.	<2 mm.	Total sand 2–0.05 mm.	Total silt 0.05–0.002 mm.	Total clay <0.002 mm.
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
0–8	Dark brown silt loam	10. 1	89. 9	38. 1	54. 3	7. 6
8–16	Brown silt loam to loam	39. 8	60. 2	29. 6	52. 6	17. 8
16–33	Brown loam with sandstone fragments	27. 4	72. 6	45. 0	36. 0	19. 0
33–51	Decomposed sandstone with sandstone fragments	40. 2	59. 8	70. 8	16. 1	13. 1
51–96	Slightly decomposed sandstone with few fragments	4. 8	95. 2	75. 4	13. 4	11. 2
	LYSIMETER Y102, MUSKINGUM SILT LOAM (SHALE)					
0–7	Brown to yellowish-brown silt loam	8. 2	91. 8	28. 9	63. 4	7. 7
7–14	Yellowish-brown silt loam slightly heavier than surface soil.	3. 2	96. 8	27. 1	54. 7	18. 2
14–24	Yellowish-brown silt loam to fine sandy loam	6. 2	93. 8	54. 9	27. 3	17. 7
24–39	Decomposed sandy shale	1. 1	98. 9	61. 0	24. 8	14. 2
39–46	Mottled gray and rust-brown clay shale	24. 8	75. 2	48. 8	33. 9	17. 3
46–60	Decomposed silty shale	53. 3	46. 7	57. 9	28. 7	13. 4
60–74	Shale in first stages of decomposition	(2)	---	---	---	---
74–96	Bedrock (shale)	(2)	---	---	---	---

LYSIMETER Y103, KEENE SILT LOAM

0–8	Gray-brown silt loam	1. 1	98. 9	10. 6	78. 4	11. 0
8–15	Yellowish-brown silt loam, unmottled	5. 2	94. 8	8. 1	77. 8	14. 1
15–27	Yellowish-brown silt loam to silty clay loam slightly mottled with gray.	2. 4	97. 6	9. 1	63. 4	27. 5
27–41	Mottled gray, yellowish-brown, and rust-brown silty clay; gray predominant.	0. 5	99. 5	9. 3	53. 1	37. 6
41–60	Gray heavy silty clay containing shale fragments	2. 2	97. 8	8. 2	54. 2	37. 6
60–83	Mostly decomposed clay shale	74. 3	25. 7	8. 8	62. 4	28. 8
83–96	Partially decomposed clay shale	76. 8	23. 2	14. 2	62. 1	23. 7

[1] Analyses by F. R. Dreibelbis and F. A. Post.
[2] No data.

TABLE 3.—*Chemical analysis of typical profiles of soils adjacent to lysimeters Y101, Y102, and Y103* [1]

Soil depth (inches)	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Loss on ignition	Total	N	Organic matter	Ratio of OM to N	Base exchange capacity M.E.[3]	pH[2]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*			
LYSIMETER Y101, MUSKINGUM SILT LOAM (SANDSTONE ORIGIN)																		
0-8	72.56	1.12	4.26	11.46	0.40	0.34	0.86	1.98	0.50	0.16	0.16	6.33	100.13	0.13	2.650	20.4	6.15	5.10
8-16	75.45	1.03	4.19	12.31	.07	.16	.82	2.15	.47	.09	.09	3.78	100.51	.03	.333	11.1	3.34	4.70
16-27	72.70	.95	5.21	13.71	.03	.12	.80	2.06	.68	.09	.05	4.15	100.47	.03	.206	6.9	5.36	4.55
27-40	74.50	.81	4.28	12.81	.06	.12	.90	2.50	.71	.05	.08	3.23	100.05	.02	.186	9.3	3.94	4.60
40-54	70.07	1.01	4.37	15.99	.04	.13	.95	2.75	.48	.05	.02	4.02	99.88	.02	.146	7.3	5.21	4.40
54-96	85.53	.38	4.36	6.02	.07	.04	.34	1.56	.34	.07	.16	1.58	100.45	.01	.062	6.2	1.41	5.20
LYSIMETER Y102, MUSKINGUM SILT LOAM (SHALE ORIGIN)																		
0-7	75.34	1.13	3.81	11.17	0.18	0.29	0.88	2.07	0.48	0.12	0.23	5.08	100.78	0.10	2.130	21.3	5.70	5.15
7-14	73.19	1.08	4.43	12.83	.05	.19	.94	2.26	1.06	.08	.04	4.32	100.47	.04	.380	9.5	4.76	4.75
14-24	69.01	.99	5.54	15.55	.06	.08	1.08	2.35	.45	.08	.01	4.83	100.03	.03	.241	8.0	5.74	4.70
24-39	67.48	1.21	5.35	16.71	.06	.04	1.20	2.64	.97	.09	.12	4.70	100.57	.03	.324	10.8	4.39	4.30
39-60	63.98	1.22	6.93	18.66	.06	.17	1.57	3.03	.54	.12	.13	6.40	99.81	.03	.369	12.3	5.76	4.40
60-96	65.63	1.17	7.52	15.76	.06	.11	1.46	2.85	.74	.15	.15	4.97	100.57	.03	.353	11.8	5.92	4.60
LYSIMETER Y103, KEENE SILT LOAM																		
0-7	75.20	1.12	4.88	10.00	0.30	0.33	0.68	1.91	0.18	0.10	0.06	5.65	100.41	0.12	2.260	18.8	9.32	5.60
7-15	70.46	1.12	5.02	12.76	.10	.32	.92	2.27	.83	.08	.03	5.88	99.79	.05	.508	10.2	9.03	5.50
15-27	70.00	1.11	6.54	13.39	.05	.26	.81	2.13	.48	.08	.04	5.79	100.68	.04	.333	8.8	9.45	4.90
27-36	63.56	1.20	5.36	18.87	.02	.08	1.08	2.73	.53	.07	.02	6.85	100.37	.04	.204	5.1	8.43	4.65
36-41	62.71	1.02	12.44	14.48	.13	.08	.70	2.15	.34	.33	.03	6.27	100.68	.03	.153	5.1	8.65	4.80
41-76	67.13	1.33	3.94	17.99	.04	.03	.84	2.99	.21	.08	.03	5.86	100.47	.04	.255	6.4	8.92	5.10
76-96	58.70	1.22	7.60	19.24	.14	.14	1.11	3.10	.91	.12	.02	7.44	99.74	.04	.292	7.3	11.47	5.50

[1] Analyses by Joe Schelling and F. R. Dreibelbis.

[2] Determined electrometrically on air-dry samples using the glass electrode.

[3] M. E. = milligram equivalents.

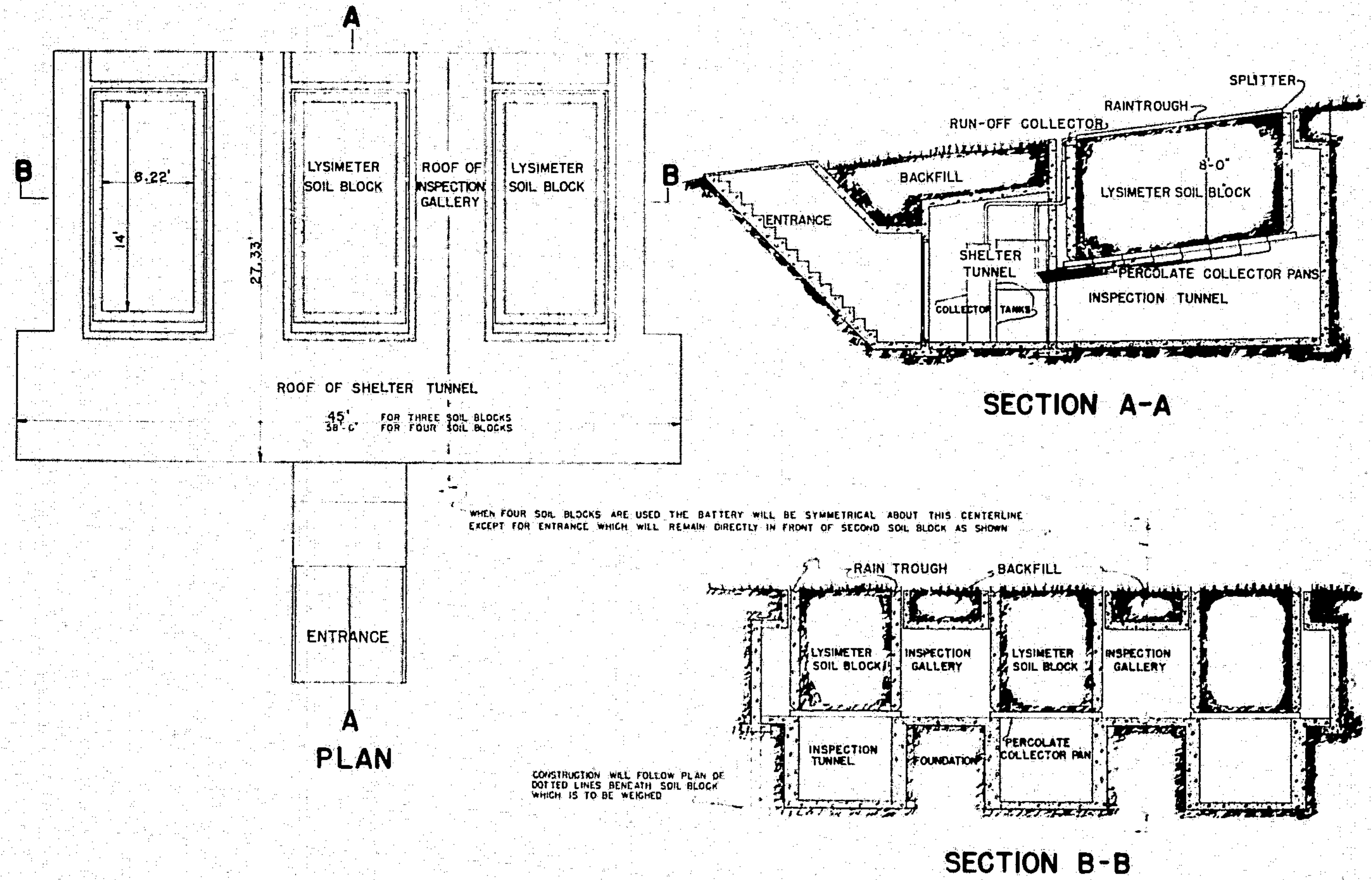

FIGURE 2.—Plan and typical cross section of a battery of water-cycle lysimeters.

FIGURE 3.—Casing weighted with sand bags to facilitate lowering in partly excavated trench.

engine. Here they reduce any tendency for water to flow down the contact surface between soil and concrete retaining wall. Lowering of the casing (fig. 3) was facilitated by adding weight to the top and partly excavating the trench below the wall.

The bottom of the soil monolith is supported by perforated steel pans that were jacked along the bottom edge of the 8-foot concrete wall casing (fig. 4) until the entire unit was enclosed and sealed. Concrete footer walls support the entire mass. One lysimeter in each battery is supported by the steel beams of the weighing mechanism. Figure 5 shows the surface of lysimeter battery Y102 after construction was completed.

RECORDING FEATURES

Each lysimeter is equipped to record automatically and continuously the surface runoff and percolation. Runoff from uphill areas is directed around the lysimeter. Lysimeter runoff is collected by trough at the downhill end and piped to a large tank where it accumulates. A water level recorder operates on each runoff collector tank, separately for each lysimeter. Percolation water that reaches the 8-foot soil depth is drained by pipe to collector tanks, separately for each lysimeter. Water level recorders on these tanks provide data on time, amounts, and rates of percolation.

One lysimeter in each of the three batteries is equipped for weighing. The *weighing mechanism* consists of scales operating on the lever and pendulum principles. They were installed by jacking up the complete lysimeter, rolling the scale frame into place beneath it, and then lowering the lysimeter until the scale frame carried the entire load of about 65 tons. Dead weight below the expected range in weight

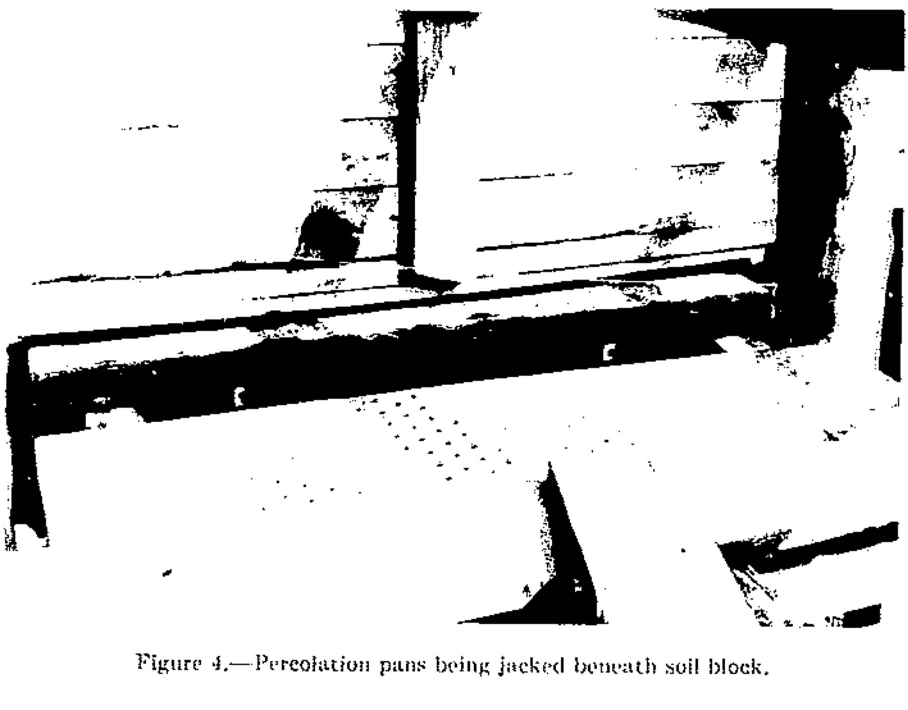

Figure 4.—Percolation pans being jacked beneath soil block.

variance was eliminated by counterbalances. After installation, the scales were tested over a 20,000-pound range by the United States National Bureau of Standards. The mechanism was found to measure weight changes to the nearest 5 pounds, which is slightly more than the weight of 0.01 inch of water on the lysimeter area. Every 10 minutes the mechanism operates automatically to print on a paper tape the time, date, and the weight. The clock is spring-driven and the printing mechanism is actuated by electricity.

Grease placed in the narrow cup-shaped gap separating the movable lysimeter from the surrounding soil at the ground surface permitted the weighing lysimeters to move freely and at the same time prevented

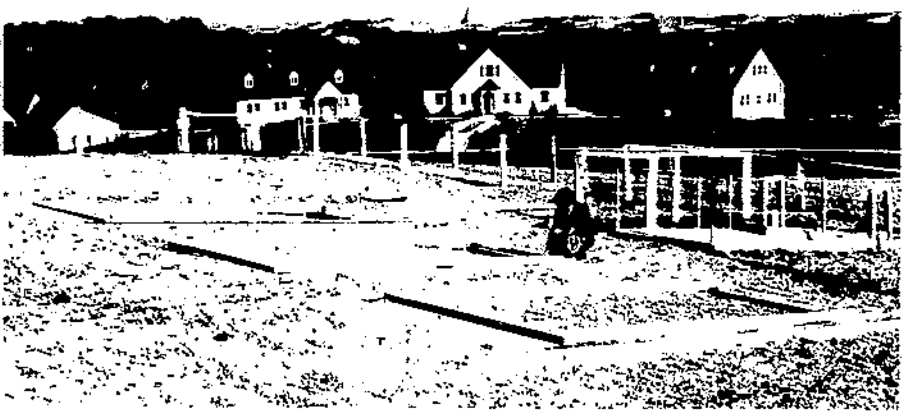

Figure 5.—Surface of lysimeter battery Y102 after construction was completed.

Table 4.—*Date on which records for each lysimeter began*

Lysimeter	Runoff	Percolation	Scale weights
Y101A	Jan. 17, 1938	Dec. 31, 1937	None.
Y101B	Jan. 10, 1938	do	June 1, 1939.[1]
Y101C	do	do	None.
Y101D	Dec. 31, 1942	Dec. 31, 1942	June 3, 1943.
Y102A	Jan. 6, 1938	Dec. 31, 1937	None.
Y102B	do	do	Do.
Y102C	do	Dec. 30, 1937	May, 1937.
Y103A	Apr. 23, 1940	Apr. 26, 1940	May 11, 1939.
Y103B	Mar. 11, 1940	Mar. 11, 1940	None.
Y103C	do	do	Do.
Y103D	Mar. 19, 1940	Mar. 20, 1940	Do.

[1] Scales transferred from Y101B to Y101D in June 1943.

air and water from entering the shelter tunnel. The grease allowed the lysimeter to move with very little friction as evidenced by the sensitivity of the scale needle during periods of gusty winds. The seal also helped to keep the temperature in the shelter tunnels and lysimeter soils the same as in the soil of adjacent crop fields.

The dates on which runoff, percolation, and scale weight records for each lysimeter began are given in table 4.

EXPERIMENTAL PROCEDURE

AGRICULTURAL OPERATIONS ON LYSIMETERS

Cultural treatments on the lysimeters were designed to provide measurements needed to evaluate the hydrology of: (1) Permanent grasses and legumes on well-drained soil; (2) a crop rotation of corn, wheat, and 2 years of meadow on well-drained soil; and (3) a similar rotation on slowly permeable soil. Agricultural operations were carried on at the same time and at the same intensity as in the adjacent farm fields. Hand tools were used in working the lysimeter soil. The abnormal border effect common to many lysimeters was overcome by extending the cropping area around each battery a distance of at least 25 feet in all directions. For example, corn rows on the lysimeters were extended into the bordering area for at least 25 feet, and parallel rows were planted on the contour above and below the lysimeters. The entire crop on each lysimeter was removed at the regular harvest time and yield determinations were made. Lysimeters Y102B and Y102C were irrigated in 1953, 1954, and 1955.

A complete history of land-use operations and yields for each lysimeter for the 1936–55 period, by years, appears in the appendix.

IRRIGATION OPERATIONS ON LYSIMETERS

To meet the growing demand for data on crop use of water where adequate water is available at all times in the growing season, an irrigation program was started on lysimeters Y102B and Y102C in the corn year 1953. Whenever half of the available moisture in 2 feet of soil became exhausted, water was applied to raise the moisture content of this part of the profile to the 100-percent level. Care was taken not to exceed the field capacity of this soil depth. Crop-rotation lysimeters at site Y102 were selected for irrigation because this soil is more droughty than at site Y103. Irrigation was applied on corn in the summer of 1953, on wheat seed for germination in October 1953, on new meadow in 1954, and on first-year meadow in 1955.

LYSIMETER RECORDING APPARATUS

Surface runoff from each lysimeter was piped to separate tanks where the water accumulated and the depth was automatically and continuously recorded. From these charts, tabulations were made to provide data on runoff totals, rates, and time, by storms, days, months, and years.

Percolating waters that reached the 8-foot depth were piped to separate tanks for accumulation. Here the depth was recorded and data were tabulated in the same way as for runoff.

Chemical analysis was made of percolate samples taken from each percolation tank each time it was drained. Nitrates were determined soon after sampling. Concentrations of other solutes were determined from composites of several samples from the same percolation tank.

Weight data were tabulated separately from the printed tapes taken from each of the weighing lysimeters and averaged for periods of an hour. Weight-change figures for various time periods were converted to inches of water depth over the 0.002-acre surface area by multiplying by 0.002207. The water-depth values were summarized by days, months, and years.

Weight change for the period of day when the lysimeter was constantly losing weight was converted to inches and labeled daily ET (evapotranspiration). Likewise, consistent gains in weight were labeled CA (condensation and absorption). With few exceptions ET values represented the overall soil-moisture change from the greatest to the least weight figure for each day, and CA values represented the overall weight increase from the daily minimum to the subsequent maximum weight value for the day. Minor fluctuations in weight between these daily extremes were not used in the computations. During periods of rainfall CA and ET were assumed to be zero. Percolation rates were considered and the weight-change values were modified in the computation of separate ET and CA values.

Daily ET−CA values are the net loss of soil moisture for the 24-hour period. If there was no precipitation, runoff, or percolation during this 24-hour period, ET−CA was obtained directly from the weight-change figures. Otherwise, the following formula was used:

ET−CA=Lysimeter Precipitation −Runoff−Percolation−Storage Change.

Runoff and percolation values were obtained from the individual recorders. Storage-change values for the day were read from the hourly weight summary and converted to inches of water. Lysimeter precipitation values were computed from the lysimeter weight-increase figures during the period of rainfall. The beginning and ending time of the rain period was taken from the recording rain-gage chart. The following formula was used:

Lysimeter Precipitation=Runoff+Percolation+Weight Increase (all from the time precipitation began until it ended)

Values of daily precipitation obtained by this formula differed noticeably at times from those obtained from the recording rain gage not more than 25 feet away. This variation is discussed in a later section.

Hygrothermograph records provided continuous data on air temperature and moisture at a height of 30 inches above the ground surface.

Thermograph records provided continuous data on air temperature at 2 inches above the ground surface and at soil depths of ½, 3, 6, 12, and 24 inches.

Evaporation records for most of the period of lysimeter record were obtained from a sunken pan 6 feet in diameter and 2 feet deep. The rim projected 4 inches above the ground surface and the water level was maintained at about 4 inches below the rim. The evaporation records were obtained through the nonfreezing period, April–October. An anemometer at this pan provided data on wind movement for 24-hour periods.

Barometric pressure was measured by a continuously recording barograph.

Soil-moisture observations on areas adjacent to the lysimeters were made periodically using field samples and Fiberglas-gypsum blocks developed at this station (*134*). No soil-moisture observations were made within the lysimeters so as not to destroy the natural soil structure. Fiberglas-gypsum blocks, however, were placed in the plow layer of the lysimeters in battery Y102 for special observations in connection with irrigation studies. Since these lysimeters were in 4-year rotation, the disturbance of soil structure by block placement in the 0- to 7-inch depth was hardly objectionable because normal tillage practices also disturbed the structure in this layer.

In order to evaluate properly the basic factors affecting water conservation and utilization, it was necessary to obtain soil-moisture data for several different layers of the profile and to make frequent determinations of soil moisture during periods of rapid accretion and depletion. Moisture observations were made on the areas adjacent to Y102 (Muskingum silt loam) and Y103 (Keene silt loam) at the following depths: 0–1, 1–4, 4–7, 7–10, 10–14, 14–24, and 24–40 inches.

Field sampling for gravimetric determinations of soil moisture not only required much time and labor but also cut up the field unduly. Therefore, this method was replaced by the electrical-resistance method using Fiberglas-gypsum blocks. The sensitivity of the blocks in the range between field capacity and saturation made it possible to obtain reasonably accurate results in the entire range of moisture from saturation to the wilting point for the soils at the Coshocton station.

Soil-water-plant relationships are of greatest importance in the top 40 inches of the profile because in this area most if not all of the plant roots lie within this zone. Using soil-moisture data together with daily accretion and depletion data from the weighing lysimeters, it was possible to construct a soil-moisture graph representing the 0- to 40-inch depth of soil to show probable daily changes throughout the year.

In the construction of this graph certain assumptions were necessary relative to accretion and depletion. These assumptions, with some flexibility in their application, are as follows:

1. ET was assumed to come from the 0- to 40-inch depth of soil on Y102C and Y103A (each a 4-year rotation) regardless of season. On Y101D, which was in alfalfa-bromegrass cover, it is likely some ET came from below the 40-inch depth.
2. In the winter when the soil was frozen, all precipitation that did not run off was assumed to be contained within the 0- to 40-inch depth.
3. All precipitation was assumed to be contained within the 0- to 40-inch layer when its soil-moisture content was less than field capacity. When above field capacity, the first 0.5 inch of precipitation was considered to be contained within the 0- to 40-inch layer. When rainfall exceeded 0.5 inch, one-third of the additional amount was attributed to this layer and the balance was attributed to the zone below 40 inches. The resulting soil-moisture curve is believed to be accurate within ± 0.5 inch with few exceptions, and often closer than ± 0.2 inch. Some values on the calculated graph of soil moisture appeared to be more reliable than the sampled points.

LIMITATIONS OF THE LYSIMETERS

Cultural operations on the lysimeters were necessarily limited to one standard crop rotation of 4 years on two of the lysimeter batteries and a permanent grass cover on the third. Facilities did not permit making a study of the hydrology of mature woodland or the hydrologic effects of such conservation measures as reforestation, different cropping systems, and mulching. The permanent-grass lysimeters, representing pasture areas, were clipped to correspond with pasturing periods, but since actual grazing of the lysimeters was impractical, the effect of stock trampling on the soil surface could not be obtained.

Every effort was made to work the surface of the lysimeter soils in such a way that their physical condition would correspond to that of the adjacent watersheds. However, the heavy implements used in the cultivation of adjacent farm fields could not be used on the crop-rotation lysimeters. Cultivation with hand tools and the weight of a workman probably had less effect on soil compaction than cultivation with mechanized farm equipment.

The lysimeters in this study were not designed to measure surface runoff other than from the lysimeters. Runoff from upper-lying areas was diverted around the lysimeter. All crops were planted on the contour. No waterways were provided to carry runoff water downhill to the collecting trough. Runoff occurred in the form of sheet flow or in small rills. All these limitations in the lysimeters are common to plot studies. The concentration and development of surface flow on plots or lysimeters, therefore, is not truly representative of natural field flows. The runoff data were needed, however, for complete evaluation of all the hydrologic factors affecting disposal of precipitation. The only lysimeter runoff data presented herein are monthly totals (tables 5, 6, and 7) and annual totals (figs. 6–17).

The walls of the lysimeter casings prevented the lateral movement of water from or to the surrounding area. This was no serious limitation for lysimeter batteries Y101 and Y102 as the soil profiles are well drained, at least to the 8-foot depth. It is unlikely, therefore, that water moved laterally in these lysimeters or even in the surrounding area. Spring or seep spots were found only at lower elevations along the hillside. For the heavier soils of lysimeter battery Y103, lateral movement of water may have occurred naturally in the unconfined areas outside the lysimeters during the temporary periods of perched water tables. The effect of the lysimeter walls in preventing lateral movement of water on percolation and soil-moisture values is believed to be small. Except in periods of perched water tables, the walls would have no effect on the functions of battery Y103.

The accuracy of the weight records used for determination of soil-moisture storage changes depended on maintaining sufficient clearance between the weighing lysimeters and the stationary walls or other objects to permit free movement of the lysimeter. Because of the jamming of the weighing apparatus in the early years of lysimeter operation, the hourly weight readings prior to 1944 were of doubtful value. As the midnight values were unaffected, they were used without reservation in determining reliable daily ET—CA values. Separate ET and CA values were not derived.

The net daily loss in weight of the lysimeters unaccounted for by runoff or percolation was designated evapotranspiration (ET). Beginning in 1945, these daily changes in weight were divided into periods of increase (CA) and decrease (ET). The net change for the day was designated ET minus CA. All daily changes in storage were calculated for the items ET, CA, and ET−CA. This permitted an evaluation of the importance of periods of soil-moisture increases and decreases separately. Snow drifting on or off the lysimeters gave abnormal weight readings. Whenever this happened, the corresponding values of ET and CA are footnoted.

ET values, as derived from lysimeter weight records by the methods presented herein, can be used in many hydrologic evaluations. They may be used with precipitation data to derive runoff values. For runoff determinations, however, some adjustment must be made for differences between values of raingage and lysimeter-measured rainfall, and for CA that is not measured. These adjustments can be applied either to the precipitation data in the area under study or to the ET values in this report. The latter procedure, which is probably the simpler, is as follows:

Annual ET minus CA minus 4 inches (precipitation-gage-data correction) equals an adjusted evapotranspiration value that can be used with precipitation-gage data. For example, with an average annual ET value of 42.2 inches, CA of 10.3 inches, and a gage correction of 4 inches, the usable evapotranspiration value would be 27.9 inches. Thus, if the precipitation-gage records in the study area show an annual value of 40 inches, the precipitation-minus-evapotranspiration value would be 40−27.9, or about 12 inches. This remainder is commonly attributed to runoff.

The limitations mentioned above illustrate some of the difficulties involved in obtaining accurate lysimeter and necessary related data. In spite of the limitations, these hydrologic data are believed to be the most reliable of their kind that have been obtained, either by actual measurement or by the use of theoretical formulas.

ANALYSIS OF RECORDS

The records obtained by means of the three automatic weighing lysimeters furnished basic data for analyses applicable to a wide field of agricultural hydrology. Results were derived in terms of soil-moisture storage changes, saturation deficiencies, rates of soil-moisture depletion by crops, evapotranspiration, condensation and absorption of atmospheric moisture, amounts and rates of percolation, and plant-nutrient losses in percolates. The data represent a period of 12 years. Irrigation data are available for only 3 years. The results and conclusions may be modified as additional data are obtained.

THE LYSIMETER AS A DEVICE FOR MEASURING THE ACCRETION AND DEPLETION OF SOIL MOISTURE

The lysimeters provided a means of measuring the accretion of moisture to the soil, depletion from the soil, and water-storage changes within the soil block. Monthly and annual summaries of these data for Y101D, Y102C, and Y103A for the period 1944–55 are given in tables 5, 6, and 7. The daily fluctuations

TABLE 5.—*Monthly summary of the accretion, depletion, and storage of soil water as determined by the weighing monolith lysimeter Y101D, 1944–55*

Year, month, and crop grown	Accretion			Depletion				Storage in 8-foot profile	
	Precipitation	Condensation	Total	Runoff	Evapotranspiration	Percolation	Total	Net increase	Net decrease
1944—Poverty grass:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	0.92	0.51	1.43	0	0.77	0.07	0.84	0.59	--------
February	1.97	.88	2.85	0	1.55	.11	1.66	1.19	--------
March	5.71	.95	6.66	.02	2.70	2.40	5.12	1.54	--------
April	3.71	.46	4.17	.01	2.27	2.73	5.01	--------	0.84
May	2.16	.22	2.38	.04	3.73	1.04	4.81	--------	2.43
June	3.09	.23	3.32	.22	4.42	.55	5.19	--------	1.87
July	2.42	.22	2.64	.14	4.70	.22	5.06	--------	2.42
August	4.27	.27	4.54	.48	3.81	.01	4.30	.24	--------
September	1.82	.44	2.26	.10	2.41	0	2.51	--------	.25
October	1.83	.66	2.49	.11	2.01	0	2.12	.37	--------
November	1.23	.43	1.66	0	1.03	0	1.03	.63	--------
December	2.83	[1] 1.87	4.70	0	[1] 1.82	0	1.82	2.88	--------
Total	31.96	7.14	39.10	1.12	31.22	7.13	39.47	7.44	7.81
Percentage of total accretion or depletion	*Percent* 81.74	*Percent* 18.26	*Percent* 100.00	*Percent* 2.84	*Percent* 79.10	*Percent* 18.06	*Percent* 100.00	--------	--------
1945—Bluegrass:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	1.68	[1] 4.29	5.97	0	[1] 3.69	0	3.69	2.28	--------
February	2.60	[1] 3.71	6.31	0	[1] 4.27	.64	4.91	1.40	--------
March	7.87	.86	8.73	.01	3.12	5.74	8.87	--------	0.14
April	4.48	.51	4.99	.02	2.94	1.97	4.93	.06	--------
May	4.67	.46	5.13	.04	3.68	2.44	6.16	--------	1.03
June	3.51	.35	3.86	.02	4.81	1.01	5.84	--------	1.98
July	2.66	.49	3.15	.01	5.78	.47	6.26	--------	3.11
August	.94	.56	1.50	.01	3.75	.20	3.96	--------	2.46
September	9.67	.44	10.11	.02	2.85	.02	2.89	7.22	--------
October	2.91	.61	3.52	.01	3.13	.81	3.95	--------	.43
November	3.90	.88	4.78	0	1.81	.70	2.51	2.27	--------
December	2.17	1.13	3.30	.09	1.63	1.35	3.07	.23	--------

Total	47.06	14.29	61.35	.23	44.46	15.35	57.04	13.46	9.15
Percentage of total accretion or depletion.	*Percent* 76.71	*Percent* 23.29	*Percent* 100.00	*Percent* .41	*Percent* 72.68	*Percent* 26.91	*Percent* 100.00		
1946—Bluegrass:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	1.06	[1] 1.76	2.82	0	[1] 2.40	1.12	3.52		0.70
February	4.48	[1] 1.45	5.93	.03	2.45	1.88	4.36	1.57	
March	2.61	.92	3.53	0	3.55	2.11	5.66		2.13
April	1.84	.76	2.60	0	4.37	.80	5.17		2.57
May	6.27	.52	6.79	.02	4.49	.42	4.93	1.86	
June	7.20	.33	7.53	.05	6.72	1.49	8.26		.73
July	5.81	.33	6.14	.02	6.21	.86	7.09		.95
August	2.71	.72	3.43	.01	4.56	.32	4.89		1.46
September	.99	.90	1.89	0	3.12	.10	3.22		1.33
October	4.62	.77	5.39	.01	2.50	.02	2.53	2.86	
November	2.66	.83	3.49	0	1.88	.09	1.97	1.52	
December	2.77	[1] 1.32	4.09	0	[1] 1.92	.67	2.59	1.50	
Total	43.02	10.61	53.63	.14	44.17	9.88	54.19	9.31	9.87
Percentage of total accretion or depletion	*Percent* 80.22	*Percent* 19.78	*Percent* 100.00	*Percent* .26	*Percent* 81.51	*Percent* 18.23	*Percent* 100.00		
1947—Brome-alfalfa:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	5.39	1.49	6.88	0	2.08	3.26	5.34	1.54	
February	1.11	[1] 2.40	3.51	0	[1] 2.79	1.93	4.72		1.21
March	2.45	[1] 1.65	4.10	.10	[1] 3.01	1.01	4.12		.02
April	4.47	.86	5.33	0	3.65	1.65	5.30	.03	
May	6.49	.85	7.34	.03	4.08	3.10	7.21	.13	
June	5.61	.51	6.12	.02	5.98	2.85	8.85		2.73
July	2.78	.65	3.43	0	5.76	.73	6.49		3.06
August	3.60	.66	4.26	.01	4.28	.28	4.57		.31
September	3.10	.69	3.79	0	4.96	.04	5.00		1.21
October	.94	.86	1.80	0	2.84	0	2.84		1.04
November	2.32	.73	3.05	0	.95	0	.95	2.10	
December	1.19	.81	2.00	0	.89	0	.89	1.11	
Total	39.45	12.16	51.61	.16	41.27	14.85	56.28	4.91	9.58
Percentage of total accretion or depletion	*Percent* 76.44	*Percent* 23.56	*Percent* 100.00	*Percent* .28	*Percent* 73.33	*Percent* 26.39	*Percent* 100.00		

See footnotes at end of table.

TABLE 5.—*Monthly summary of the accretion, depletion, and storage of soil water as determined by the weighing monolith lysimeter Y101D, 1944–55*—Continued

Year, month, and crop grown	Accretion			Depletion				Storage in 8-foot profile	
	Precipitation	Condensation	Total	Runoff	Evapotranspiration	Percolation	Total	Net increase	Net decrease
1948—Brome-alfalfa:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	2.85	[1] 1.67	4.52	0	[1] 1.74	0	1.74	2.78	------
February	3.49	1.46	4.95	0	2.32	.66	2.98	1.97	------
March	4.76	1.33	6.09	.01	3.45	1.59	5.05	1.04	------
April	4.95	.57	5.52	.01	4.66	3.26	7.93	------	2.41
May	3.25	.26	3.51	0	5.63	.08	5.71	------	2.20
June	3.09	.22	3.31	.01	4.30	.01	4.32	------	1.01
July	3.56	.37	3.93	0	5.89	0	5.89	------	1.96
August	1.04	.55	1.59	0	4.70	.01	4.71	------	3.12
September	3.15	.38	3.53	0	3.04	0	3.04	.49	------
October	2.83	.75	3.58	0	2.63	0	2.63	.95	------
November	3.22	.79	4.01	0	2.14	0	2.14	1.87	------
December	2.35	[1] 1.23	3.58	0	[1] 1.62	0	1.62	1.96	------
Total	38.54	9.58	48.12	.03	42.12	5.61	47.76	11.06	10.70
Percentage of total accretion or depletion	*Percent* 80.09	*Percent* 19.91	*Percent* 100.00	*Percent* .06	*Percent* 88.19	*Percent* 11.75	*Percent* 100.00	------	------
1949—Brome-alfalfa:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	5.40	[1] 1.08	6.48	0	[1] 1.61	0.69	2.30	4.18	------
February	2.90	[1] 1.34	4.24	0	[1] 2.06	1.15	3.21	1.03	------
March	4.17	1.41	5.58	0	3.18	1.72	4.90	.68	------
April	3.04	.89	3.93	0	4.81	1.38	6.19	------	2.26
May	2.60	.35	2.95	.01	6.84	.60	7.45	------	4.50
June	3.43	.59	4.02	.01	6.08	.04	6.13	------	2.11
July	8.24	.37	8.61	.02	6.89	0	6.91	1.70	------
August	2.74	.71	3.45	.01	5.34	0	5.35	------	1.90
September	3.38	.74	4.12	.01	4.26	0	4.27	------	.15
October	1.01	.80	1.81	0	3.47	0	3.47	------	1.66
November	1.49	.91	2.40	0	1.83	0	1.83	.57	------
December	2.81	1.54	4.35	0	1.72	0	1.72	2.63	------

Total	41.21	10.73	51.94	.06	48.09	5.58	53.73	10.79	12.58
Percentage of total accretion or depletion	*Percent* 79.34	*Percent* 20.66	*Percent* 100.00	*Percent* .12	*Percent* 89.50	*Percent* 10.38	*Percent* 100.00	------	------
1950—Brome-alfalfa:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	9.06	1.34	10.40	0.01	1.97	1.27	3.25	7.15	------
February	3.78	[1] 1.60	5.38	.01	[1] 2.28	2.46	4.75	.63	------
March	2.93	[1] 1.60	4.53	0	[1] 3.21	1.74	4.95	------	0.42
April	4.38	1.07	5.45	0	3.45	1.83	5.28	.17	------
May	4.50	.68	5.18	.02	6.08	1.06	7.16	------	1.98
June	2.08	.87	2.95	0	5.70	.47	6.17	------	3.22
July	6.51	.24	6.75	.02	7.31	.03	7.36	------	.61
August	2.49	.43	2.92	0	6.26	0	6.26	------	3.34
September	5.44	.56	6.00	.10	4.45	0	4.55	1.45	------
October	1.50	.69	2.19	0	3.49	0	3.49	------	1.30
November	6.23	[1] .84	7.07	0	[1] 1.61	0	1.61	5.46	------
December	3.24	[1] 1.09	4.33	0	[1] 2.14	.13	2.27	2.06	------
Total	52.14	11.01	63.15	.16	47.95	8.99	57.10	16.92	10.87
Percentage of total accretion or depletion	*Percent* 82.56	*Percent* 17.44	*Percent* 100.00	*Percent* .28	*Percent* 83.98	*Percent* 15.74	*Percent* 100.00	------	------
1951—Brome-alfalfa:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	6.58	[1] 1.08	7.66	0.01	[1] 2.83	2.57	5.41	2.25	------
February	4.22	[1] 1.68	5.90	0	[1] 3.12	3.46	6.58	------	0.68
March	5.78	[1] 1.53	7.31	0	[1] 2.98	3.42	6.40	.91	------
April	3.62	1.20	4.82	.01	3.67	2.73	6.41	------	1.59
May	2.33	.52	2.85	.01	6.72	1.06	7.79	------	4.94
June	5.83	.65	6.48	.02	5.05	.16	5.23	1.25	------
July	3.07	.39	3.46	0	8.14	.01	8.15	------	4.69
August	.48	.38	.86	0	3.72	0	3.72	------	2.86
September	2.72	.36	3.08	0	3.58	0	3.58	------	.50
October	2.12	.78	2.90	0	3.47	0	3.47	------	.57
November	5.34	[1] 1.12	6.46	0	[1] 1.94	0	1.94	4.52	------
December	5.85	[1] 2.54	8.39	0	[1] 4.20	0	4.20	4.19	------
Total	47.94	12.23	60.17	.05	49.42	13.41	62.88	13.12	15.83
Percentage of total accretion or depletion	*Percent* 79.67	*Percent* 20.33	*Percent* 100.00	*Percent* .08	*Percent* 78.59	*Percent* 21.33	*Percent* 100.00	------	------

See footnotes at end of table.

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TABLE 5.—*Monthly summary of the accretion, depletion, and storage of soil water as determined by the weighing monolith lysimeter Y101D, 1944–55*—Continued

Year, month, and crop grown	Accretion			Depletion				Storage in 8-foot profile	
	Precipitation	Condensation	Total	Runoff	Evapotranspiration	Percolation	Total	Net increase	Net decrease
1952—Brome-alfalfa:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	6.38	[1] 1.58	7.96	0	[1] 2.32	1.69	4.01	3.95	--------
February	3.06	[1] 1.47	4.53	.01	[1] 2.44	2.29	4.74	--------	0.21
March	4.15	[1] 1.61	5.76	0	[1] 3.15	2.03	5.18	.58	--------
April	4.56	.98	5.54	0	4.65	1.83	6.48	--------	.94
May	4.99	.61	5.60	.02	7.04	.87	7.93	--------	2.33
June	2.73	.47	3.20	.01	5.58	.09	5.68	--------	2.48
July	4.34	.41	4.75	.01	7.49	0	7.50	--------	2.75
August	2.03	.56	2.59	0	5.28	0	5.28	--------	2.69
September	2.50	.50	3.00	0	3.75	0	3.75	--------	.75
October	.69	.65	1.34	0	1.90	0	1.90	--------	.56
November	1.93	[1] 1.09	3.02	0	[1] 1.70	0	1.70	1.32	--------
December	2.66	[1] .99	3.65	0	[1] 1.31	0	1.31	2.34	--------
Total	40.02	10.92	50.94	.05	46.61	8.80	55.46	8.19	12.71
Percentage of total accretion or depletion	*Percent* 78.56	*Percent* 21.44	*Percent* 100.00	*Percent* .09	*Percent* 84.04	*Percent* 15.87	*Percent* 100.00	--------	--------
1953—Brome-alfalfa:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	5.60	[1] 1.14	6.74	0	[1] 1.60	0	1.60	5.14	--------
February	1.45	[1] 1.41	2.86	0	[1] 2.11	0	2.11	.75	--------
March	3.54	[1] 1.26	4.80	0	[1] 2.54	.22	2.76	2.04	--------
April	2.71	1.00	3.71	0	3.30	.74	4.04	--------	0.33
May	4.22	.63	4.85	.01	6.23	.54	6.78	--------	1.93
June	2.36	.47	2.83	.02	6.08	.03	6.13	--------	3.30
July	4.20	.34	4.54	0	6.16	0	6.16	--------	1.62
August	1.01	.54	1.55	0	4.62	0	4.62	--------	3.07
September	1.12	.65	1.77	0	4.19	0	4.19	--------	2.42
October	.57	.65	1.22	0	2.08	0	2.08	--------	.86
November	1.33	[1] 1.36	2.69	0	[1] 1.88	0	1.88	.81	--------
December	2.56	[1] 1.36	3.92	0	[1] 1.92	0	1.92	2.00	--------

Total	30.67	10.81	41.48	.03	42.71	1.53	44.27	10.74	13.53
Percentage of total accretion or depletion	*Percent* 73.94	*Percent* 26.06	*Percent* 100.00	*Percent* .06	*Percent* 96.48	*Percent* 3.46	*Percent* 100.00	--------	--------
1954—Brome-alfalfa:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	2.82	[1] 1.42	4.24	0.01	[1] 1.89	0	1.90	2.34	--------
February	2.21	[1] 1.34	3.55	0	[1] 2.23	0	2.23	1.32	--------
March	4.77	[1] 2.04	6.81	0	[1] 4.08	0	4.08	2.73	--------
April	3.29	1.04	4.33	0	4.65	0	4.65	--------	0.32
May	2.44	.78	3.22	0	6.16	0	6.16	--------	2.94
June	2.21	.71	2.92	.01	5.19	0	5.20	--------	2.28
July	3.39	.67	4.06	0	5.85	0	5.85	--------	1.79
August	3.57	.76	4.33	0	4.80	0	4.80	--------	.47
September	1.42	1.02	2.44	0	3.79	0	3.79	--------	1.35
October	6.24	1.01	7.25	0	2.88	0	2.88	4.37	--------
November	1.55	[1] 1.28	2.83	0	[1] 2.12	0	2.12	.71	--------
December	2.77	[1] 1.50	4.27	0	[1] 1.92	0	1.92	2.35	--------
Total	36.68	13.57	50.25	.02	45.56	0	45.58	13.82	9.15
Percentage of total accretion or depletion	*Percent* 73.00	*Percent* 27.00	*Percent* 100.00	*Percent* .04	*Percent* 99.96	*Percent* 0	*Percent* 100.00	--------	--------
1955—Brome-alfalfa:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	1.82	[1] 1.59	3.41	0	[1] 2.26	0	2.26	1.15	--------
February	3.57	[1] 1.24	4.81	.17	[1] 2.10	.12	2.39	2.42	--------
March	5.07	[1] 1.93	7.00	0	[1] 3.97	1.05	5.02	1.98	--------
April	3.89	.99	4.88	.01	5.24	.44	5.69	--------	0.81
May	1.70	.57	2.27	0	6.79	.09	6.88	--------	4.61
June	[2] 6.74	.76	[2] 7.50	0	5.56	0	5.56	1.94	--------
July	3.82	.60	4.42	0	6.86	0	6.86	--------	2.44
August	3.66	.76	4.42	0	5.36	0	5.36	--------	.94
September	2.45	.94	3.39	0	4.07	0	4.07	--------	.68
October	2.40	1.06	3.46	0	3.09	0	3.09	.37	--------
November	[1] 3.54	[1] 1.23	4.77	0	[1] 2.00	0	2.00	2.77	--------
December	.35	[1] 1.67	2.02	0	[1] 2.04	0	2.04	--------	.02
Total	39.01	13.34	52.35	.18	[1] 49.34	1.70	51.22	10.63	9.50
Percentage of total accretion or depletion	*Percent* 74.52	*Percent* 25.48	*Percent* 100.00	*Percent* .35	*Percent* 96.33	*Percent* 3.32	*Percent* 100.00	--------	--------

[1] Some snowfall during the month; some values may be too high because of drifting of snow.

[2] Includes irrigation of 3.61 inches.

TABLE 6.—*Monthly summary of the accretion, depletion, and storage of soil water as determined by the weighing monolith lysimeter Y102C, 1944–55*

Year, month, and crop grown	Accretion			Depletion				Storage in 8-foot profile	
	Precipitation	Condensation	Total	Runoff	Evapotranspiration	Percolation	Total	Net increase	Net decrease
1944—Meadow:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	1.13	1.10	2.23	0	1.52	0	1.52	0.71	------
February	1.97	.66	2.63	.02	1.28	.01	1.31	1.32	------
March	6.98	.39	7.37	.02	2.01	3.47	5.50	1.87	------
April	4.30	.32	4.62	.01	2.28	3.22	5.51	------	0.89
May	2.49	.11	2.60	0	4.53	.50	5.03	------	2.43
June	3.80	.12	3.92	.05	4.52	.10	4.67	------	.75
July	2.72	.20	2.92	.06	4.25	.02	4.33	------	1.41
August	4.72	.19	4.91	.16	4.38	0	4.54	.37	------
September	2.07	.43	2.50	.04	3.16	0	3.20	------	.70
October	1.90	.76	2.66	.01	2.26	0	2.27	.39	------
November	1.48	.81	2.29	0	1.69	0	1.69	.60	------
December	4.55	[1] 1.44	5.99	.06	[1] 2.61	.02	2.69	3.30	------
Total	38.11	6.53	44.64	.43	34.49	7.34	42.26	8.56	6.18
Percentage of total accretion or depletion	*Percent* 85.37	*Percent* 14.63	*Percent* 100.00	*Percent* 1.02	*Percent* 81.61	*Percent* 17.37	*Percent* 100.00	------	------
1945—Corn:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	1.63	[1] 2.23	3.86	0.08	[1] 2.15	0.26	2.49	1.37	------
February	2.83	[1] 1.82	4.75	.01	[1] 2.64	2.22	4.87	------	0.12
March	9.03	.80	9.83	.19	2.79	7.74	10.72	------	.89
April	4.88	.54	5.42	.05	3.48	1.82	5.35	.07	------
May	5.32	.66	5.98	.20	4.85	1.83	6.88	------	.90
June	4.34	.57	4.91	1.09	3.97	.34	5.40	------	.49
July	2.85	.22	3.07	.08	4.72	.13	4.93	------	1.86
August	1.23	.47	1.70	.05	4.18	.04	4.27	------	2.57
September	9.66	.44	10.10	2.03	3.40	0	5.43	4.67	------
October	2.74	.91	3.65	.39	3.24	.25	3.88	------	.23
November	3.85	.99	4.84	.05	2.32	.67	3.04	1.80	------
December	2.40	[1] 1.13	3.53	.40	[1] 1.87	.93	3.20	.33	------

Total	50. 86	10. 78	61. 64	4. 62	39. 61	16. 23	60. 46	8. 24	7. 06
Percentage of total accretion or depletion	*Percent* 82. 51	*Percent* 17. 49	*Percent* 100. 00	*Percent* 7. 64	*Percent* 65. 51	*Percent* 26. 85	*Percent* 100. 00		
1946—Wheat:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	1. 09	[1] 1. 58	2. 67	0. 05	[1] 2. 44	1. 08	3. 57		0. 90
February	4. 63	1. 16	5. 79	. 11	[1] 2. 32	2. 46	4. 89	0. 90	
March	2. 61	1. 05	3. 66	. 01	3. 84	1. 66	5. 51		1. 85
April	1. 87	. 68	2. 55	0	5. 11	. 24	5. 35		2. 80
May	5. 98	. 36	6. 34	. 02	5. 20	. 08	5. 30	1. 04	
June	6. 72	. 17	6. 89	. 02	5. 72	. 07	5. 81	1. 08	
July	5. 33	. 37	5. 70	. 04	5. 59	. 10	5. 73		. 03
August	2. 40	. 52	2. 92	0	5. 21	. 12	5. 33		2. 41
September	. 88	. 77	1. 65	0	3. 22	. 02	3. 24		1. 59
October	4. 38	. 89	5. 27	. 02	2. 69	. 03	2. 74	2. 53	
November	2. 74	1. 11	3. 85	. 01	2. 18	. 04	2. 23	1. 62	
December	2. 83	[1] 1. 26	4. 09	. 01	[1] 2. 06	. 15	2. 22	1. 87	
Total	41. 46	9. 92	51. 38	. 29	45. 58	6. 05	51. 92	9. 04	9. 58
Percentage of total accretion or depletion	*Percent* 80. 70	*Percent* 19. 30	*Percent* 100. 00	*Percent* . 56	*Percent* 87. 79	*Percent* 11. 65	*Percent* 100. 00		
1947—Meadow:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	5. 35	[1] 1. 49	6. 84	. 02	[1] 2. 03	4. 10	6. 15	0. 69	
February	1. 15	[1] 1. 77	2. 92	. 06	[1] 2. 51	1. 16	3. 73		0. 81
March	2. 33	1. 17	3. 50	. 11	2. 76	. 42	3. 29	. 21	
April	4. 28	. 94	5. 22	. 01	3. 13	2. 01	5. 15	. 07	
May	6. 43	. 74	7. 17	. 03	4. 64	3. 00	7. 67		. 50
June	5. 65	. 44	6. 09	. 04	6. 62	1. 46	8. 12		2. 03
July	2. 84	. 45	3. 29	. 01	5. 81	. 08	5. 90		2. 61
August	3. 76	. 73	4. 49	. 01	4. 78	. 02	4. 81		. 32
September	3. 13	. 50	3. 63	0	5. 42	. 01	5. 43		1. 80
October	1. 04	. 80	1. 84	0	3. 37	0	3. 37		1. 53
November	2. 67	1. 03	3. 70	0	1. 76	. 01	1. 77	1. 93	
December	1. 49	1. 22	2. 71	0	1. 69	. 01	1. 70	1. 01	
Total	40. 12	11. 28	51. 40	. 29	44. 52	12. 28	57. 09	3. 91	9. 60
Percentage of total accretion or depletion	*Percent* 78. 05	*Percent* 21. 95	*Percent* 100. 00	*Percent* . 51	*Percent* 77. 98	*Percent* 21. 51	*Percent* 100. 00		

See footnotes at end of table.

TABLE 6.—*Monthly summary of the accretion, depletion, and storage of soil water as determined by the weighing monolith lysimeter Y102C, 1944–55*—Continued

Year, month, and crop grown	Accretion			Depletion				Storage in 8-foot profile	
	Precipitation	Condensation	Total	Runoff	Evapotranspiration	Percolation	Total	Net increase	Net decrease
1948—Meadow:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	3.42	1.58	5.00	0	1.94	0.01	1.95	3.05	
February	3.14	2.10	5.24		2.54	.14	2.69	2.55	
March	4.80	1.34	6.14	.08	3.00	2.33	5.41	.73	
April	5.17	.88	6.05	.02	4.35	3.88	8.25		2.20
May	3.65	.37	4.02	0	7.05	.10	7.15		3.13
June	5.05	.26	5.31	.01	7.02	.01	7.04		1.73
July	3.57	.36	3.93	.01	6.09	.01	6.11		2.18
August	1.12	.83	1.95	0	3.93	0	3.93		1.98
September	3.74	.63	4.37	.01	3.66	0	3.67	.70	
October	2.85	.84	3.69	.01	2.77	.01	2.79	.90	
November	3.23	1.01	4.24	0	2.26	.01	2.27	1.97	
December	2.31	1.48	3.79	0	1.91	.01	1.92	1.87	
Total	42.05	11.68	53.73	.15	46.52	6.51	53.18	11.77	11.22
Percentage of total accretion or depletion	*Percent* 78.26	*Percent* 21.74	*Percent* 100.00	*Percent* .28	*Percent* 87.48	*Percent* 12.24	*Percent* 100.00		
1949—Corn:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	5.54	1.19	6.73	0.01	1.75	0.14	1.90	4.83	
February	2.85	1.19	4.04	.01	2.09	1.35	3.45	.59	
March	3.89	1.34	5.23	.01	2.90	2.02	4.93	.30	
April	2.93	.83	3.76	.01	4.02	.94	4.97		1.21
May	3.01	1.17	4.18	.06	4.07	.46	4.59		.41
June	3.40	.78	4.18	.05	5.19	.32	5.56		1.38
July	6.71	.33	7.04	.16	7.54	.18	7.88		.84
August	2.68	.69	3.37	0	5.53	.06	5.59		2.22
September	3.45	.90	4.35	.01	3.13	0	3.14	1.21	
October	1.03	1.19	2.22	0	2.81	.01	2.82		.60
November	1.55	.97	2.52	0	2.28	.02	2.30	.22	
December	2.94	1.19	4.13	0	1.96	0	1.96	2.17	

Total	39.98	11.77	51.75	.32	43.27	5.50	49.09	9.32	6.66
Percentage of total accretion or depletion	*Percent* 77.26	*Percent* 22.74	*Percent* 100.00	*Percent* .65	*Percent* 88.14	*Percent* 11.21	*Percent* 100.00	....	.....
1950 Wheat:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	9.11	1.32	10.43	0.06	2.26	4.84	7.16	3.27	
February	3.74	[1] 1.70	5.44	0	[1] 2.24	3.26	5.50		0.06
March	3.01	[1] 1.49	4.50	.04	[1] 3.11	1.85	5.00		.50
April	4.44	1.24	5.68	.02	3.43	2.02	5.47	.21	
May	4.42	.55	4.97	.01	6.17	.62	6.80		1.83
June	2.27	.46	2.73	0	5.57	.11	5.68		2.95
July	6.98	.87	7.85	.02	3.98	.04	4.04	3.81	
August	2.14	.91	3.05	0	4.84	.20	5.04		1.99
September	5.61	.72	6.33	.01	4.25	1.75	6.01	.32	
October	1.50	.77	2.27	0	3.57	.07	3.64		1.37
November	6.41	[1] 1.32	7.73	0	[1] 2.57	.06	2.63	5.10	
December	3.32	[1] 1.57	4.89	.02	2.68	2.93	5.63		.74
Total	52.95	12.92	65.87	.18	44.67	17.75	62.60	12.71	9.44
Percentage of total accretion or depletion	*Percent* 80.39	*Percent* 19.61	*Percent* 100.00	*Percent* .29	*Percent* 71.36	*Percent* 28.35	*Percent* 100.00		
1951 Meadow:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	6.41	[1] 1.17	7.58	0.10	[1] 2.62	4.10	6.82	0.76	
February	4.83	[1] 3.24	8.07	.35	[1] 4.74	4.09	9.18		1.11
March	5.80	[1] 1.50	7.30	.06	[1] 2.93	3.63	6.62	.68	
April	3.41	1.38	4.79	0	3.21	2.54	5.75		.96
May	2.38	.65	3.03	0	6.32	.51	6.83		3.80
June	5.73	.68	6.41	.01	5.69	.06	5.76	.65	
July	2.90	.46	3.36	0	7.39	.01	7.40		4.04
August	.65	1.16	1.81	0	3.29	0	3.29		1.48
September	3.02	.62	3.64	.01	3.75	0	3.76		.12
October	1.88	.72	2.60	.01	3.04	.01	3.06		.46
November	5.04	[1] 1.05	6.09	.01	[1] 1.93	.01	1.95	4.14	
December	5.78	[1] 1.85	7.63	.03	[1] 3.23	.15	3.41	4.22	
Total	47.83	14.48	62.31	.58	48.14	15.11	63.83	10.45	11.97
Percentage of total accretion or depletion	*Percent* 76.76	*Percent* 23.24	*Percent* 100.00	*Percent* .91	*Percent* 75.42	*Percent* 23.67	*Percent* 100.00	....	..

See footnotes at end of table.

TABLE 6.—*Monthly summary of the accretion, depletion, and storage of soil water as determined by the weighing monolith lysimeter Y102C, 1944–55*—Continued

Year, month, and crop grown	Accretion			Depletion				Storage in 8-foot profile	
	Precipitation	Condensation	Total	Runoff	Evapotranspiration	Percolation	Total	Net increase	Net decrease
1952—Meadow:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	6. 34	[1] 1. 57	7. 91	0. 04	[1] 2. 57	4. 13	6. 74	1. 17	
February	2. 92	[1] 1. 40	4. 32	0	[1] 2. 24	2. 72	4. 96		0. 64
March	4. 01	[1] 1. 64	5. 65	. 04	[1] 2. 87	2. 50	5. 41	. 24	
April	4. 14	1. 01	5. 15	. 02	3. 82	1. 93	5. 77		. 62
May	3. 92	. 48	4. 40	. 01	5. 94	. 37	6. 32		1. 92
June	2. 69	. 51	3. 20	. 02	6. 18	. 02	6. 22		3. 02
July	3. 94	. 43	4. 37	. 02	6. 72	0	6. 74		2. 37
August	2. 05	. 80	2. 85	. 01	4. 60	0	4. 61		1. 76
September	2. 56	. 73	3. 29	. 02	3. 74	0	3. 76		. 47
October	. 78	1. 04	1. 82	0	2. 30	. 01	2. 31		. 49
November	1. 72	[1] 1. 12	2. 84	. 01	[1] 1. 86	0	1. 87	. 97	
December	2. 64	[1] 1. 04	3. 68	0	[1] 1. 48	0	1. 48	2. 20	
Total	37. 71	11. 77	49. 48	. 19	44. 32	11. 68	56. 19	4. 58	11. 29
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		
Percentage of total accretion or depletion	76. 21	23. 79	100. 00	. 34	78. 87	20. 79	100. 00		
1953—Corn:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	5. 44	[1] 1. 10	6. 54	0. 01	[1] 1. 75	0	1. 76	4. 78	
February	1. 44	[1] 1. 21	2. 65	0	[1] 2. 08	0	2. 08	. 57	
March	3. 44	[1] 1. 15	4. 59	. 01	[1] 2. 53	. 16	2. 70	1. 89	
April	2. 61	. 91	3. 52	. 01	3. 33	. 51	3. 85		0. 33
May	4. 28	1. 08	5. 36	. 02	4. 36	1. 24	5. 62		. 26
June	2. 36	. 87	3. 23	. 03	4. 13	. 43	4. 59		1. 36
July	[2] 8. 15	. 37	8. 52	. 02	7. 16	. 39	7. 57	. 95	
August	[2] 4. 69	. 47	5. 16	. 01	7. 22	. 22	7. 45		2. 29
September	1. 10	. 75	1. 85	0	4. 20	. 05	4. 25		2. 40
October	[2] 2. 93	1. 21	4. 14	. 01	2. 61	. 01	2. 63	1. 51	
November	1. 32	[1] 1. 26	2. 58	0	[1] 2. 38	0	2. 38	. 20	
December	2. 69	[1] 1. 47	4. 16	. 04	[1] 2. 67	. 01	2. 72	1. 44	

Total	40.45	11.85	52.30	.16	44.42	3.02	47.60	11.34	6.64
Percentage of total accretion or depletion	*Percent* 77.34	*Percent* 22.66	*Percent* 100.00	*Percent* .34	*Percent* 93.32	*Percent* 6.34	*Percent* 100.00	--------	--------
1954—Wheat:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	2.97	[1] 1.72	4.69	0.23	[1] 2.50	0.05	2.78	1.91	--------
February	2.06	[1] 1.32	3.38	.05	[1] 2.41	.07	2.53	.85	--------
March	4.43	[1] 1.41	5.84	.09	[1] 3.32	1.80	5.21	.63	--------
April	2.82	1.10	3.92	.02	5.08	1.10	6.20	--------	2.28
May	2.20	.28	2.48	0	6.23	.16	6.39	--------	3.91
June	2.31	.47	2.78	0	4.58	.03	4.61	--------	1.83
July	[2] 4.45	.90	5.35	.04	3.14	0	3.18	2.17	--------
August	3.23	.74	3.97	.02	5.12	.01	5.15	--------	1.18
September	[2] 2.98	.73	3.71	.01	4.56	0	4.57	--------	.86
October	5.48	.93	6.41	.02	3.09	0	3.11	3.30	--------
November	1.43	[1] 1.19	2.62	0	[1] 2.02	0	2.02	.60	--------
December	2.68	[1] 1.45	4.13	.01	[1] 1.87	.01	1.89	2.24	--------
Total	37.04	12.24	49.28	.49	43.92	3.23	47.64	11.70	10.06
Percentage of total accretion or depletion	*Percent* 75.16	*Percent* 24.84	*Percent* 100.00	*Percent* 1.03	*Percent* 92.19	*Percent* 6.78	*Percent* 100.00	--------	--------
1955—Meadow:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	1.70	[1] 1.27	2.97	0	[1] 2.08	0.12	2.20	0.77	--------
February	3.81	[1] 1.53	5.34	.13	[1] 2.35	2.29	4.77	.57	--------
March	4.96	[1] 1.95	6.91	.14	[1] 3.03	4.02	7.19	--------	0.28
April	3.73	.95	4.68	.02	4.48	.92	5.42	--------	.74
May	[2] 3.84	.30	4.14	.01	6.90	.32	7.23	--------	3.09
June	[2] 5.99	.68	6.67	.03	5.60	.03	5.66	1.01	--------
July	3.61	.58	4.19	.01	6.75	.01	6.77	--------	2.58
August	3.12	.39	3.51	.02	6.18	0	6.20	--------	2.69
September	2.36	.82	3.18	0	3.84	0	3.84	--------	.66
October	2.23	.87	3.10	0	3.46	.01	3.47	--------	.37
November	3.48	[1] 1.44	4.92	.02	[1] 2.23	.01	2.26	2.66	--------
December	.35	[1] 1.91	2.26	0	[1] 2.22	.01	2.23	.03	--------
Total	39.18	12.69	51.87	.38	49.12	7.74	57.24	5.04	10.41
Percentage of total accretion or depletion	*Percent* 75.54	*Percent* 24.46	*Percent* 100.00	*Percent* .67	*Percent* 85.81	*Percent* 13.52	*Percent* 100.00	--------	--------

[1] Some snowfall during the month; some values may be too high because of drifting of snow.

[2] Includes irrigation:
1953—July, 2.93 inches; August, 2.90 inches; October, 2.24 inches.
1954—July, 1.13 inches; September, 1.65 inches.
1955—May, 2.26 inches; June, 3.07 inches.

TABLE 7.—*Monthly summary of the accretion, depletion, and storage of soil water as determined by the weighing monolith lysimeter Y103A, 1944–55*

Year, month, and crop grown	Accretion			Depletion				Storage in 8-foot profile	
	Precipitation	Condensation	Total	Runoff	Evapotranspiration	Percolation	Total	Net increase	Net decrease
1944—Meadow:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	1. 15	0. 73	1. 88	0	1. 14	0. 04	1. 18	0. 70	--------
February	2. 14	. 88	3. 02	0	1. 88	. 25	2. 13	. 89	--------
March	6. 10	. 62	6. 72	0	3. 28	2. 93	6. 21	. 51	--------
April	3. 83	. 49	4. 32	0	3. 05	1. 67	4. 72	--------	0. 40
May	2. 40	. 17	2. 57	0	3. 97	. 07	4. 04	--------	1. 47
June	3. 15	. 17	3. 32	. 01	5. 35	. 04	5. 40	--------	2. 08
July	2. 46	. 07	2. 53	. 01	4. 68	. 02	4. 71	--------	2. 18
August	4. 39	. 07	4. 46	. 02	4. 27	. 02	4. 31	. 15	--------
September	1. 84	. 20	2. 04	. 01	2. 89	. 01	2. 91	--------	. 87
October	1. 81	. 45	2. 26	0	1. 70	. 01	1. 71	. 55	--------
November	1. 25	. 39	1. 64	0	1. 01	0	1. 01	. 63	--------
December	4. 54	[1] 1. 56	6. 10	. 01	[1] 2. 95	0	2. 96	3. 14	--------
Total	35. 06	5. 80	40. 86	. 06	36. 17	5. 06	41. 29	6. 57	7. 00
Percentage of total accretion or depletion	*Percent* 85. 81	*Percent* 14. 19	*Percent* 100. 00	*Percent* . 15	*Percent* 87. 60	*Percent* 12. 25	*Percent* 100. 00	--------	--------
1945—Corn:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	2. 04	[1] 2. 11	4. 15	0. 04	[1] 2. 70	0	2. 74	1. 41	--------
February	2. 66	[1] 1. 53	4. 19	. 01	[1] 2. 36	1. 37	3. 74	. 45	--------
March	8. 11	. 56	8. 67	. 07	2. 79	5. 47	8. 33	. 34	--------
April	4. 89	. 26	5. 15	0	3. 72	1. 37	5. 09	. 06	--------
May	4. 82	. 29	5. 11	. 01	5. 25	. 78	6. 04	--------	0. 93
June	4. 37	. 42	4. 79	. 24	4. 53	. 06	4. 83	--------	. 04
July	2. 71	. 26	2. 97	. 02	5. 98	. 02	6. 02	--------	3. 05
August	1. 04	. 38	1. 42	0	4. 59	. 01	4. 60	--------	3. 18
September	9. 42	. 41	9. 83	. 01	2. 69	. 55	3. 25	6. 58	--------
October	2. 78	. 76	3. 54	. 01	3. 21	. 43	3. 65	--------	. 11
November	3. 61	. 67	4. 28	0	2. 21	. 76	2. 97	1. 31	--------
December	2. 15	. 82	2. 97	. 01	1. 93	. 18	2. 12	. 85	--------

Total	48.60	8.47	57.07	.42	41.96	11.00	53.38	11.00	7.31
Percentage of total accretion or depletion	*Percent* 85.16	*Percent* 14.84	*Percent* 100.00	*Percent* .78	*Percent* 78.61	*Percent* 20.61	*Percent* 100.00	--------	--------
1946—Wheat:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	0.89	[1] 1.67	2.56	0	[1] 2.23	0.80	3.03	--------	0.79
February	4.11	[1] 1.31	5.42	.01	[1] 2.34	2.19	4.54	0.53	--------
March	2.46	.82	3.28	0	3.65	1.03	4.68	--------	1.40
April	1.59	.72	2.31	0	4.53	.06	4.59	--------	2.60
May	5.92	.46	6.38	0	5.32	.03	5.35	.90	--------
June	7.16	.25	7.41	.01	6.26	.50	6.77	.68	--------
July	5.16	.35	5.51	.01	6.77	.04	6.82	--------	1.28
August	2.47	.62	3.09	0	5.61	.02	5.63	--------	2.64
September	.90	.85	1.75	0	3.43	.01	3.44	--------	1.69
October	4.42	.86	5.28	.01	2.53	.01	2.55	2.73	--------
November	2.77	.75	3.52	0	1.66	.01	1.67	1.85	--------
December	2.80	.82	3.62	0	1.62	.28	1.90	1.72	--------
Total	40.65	9.48	50.13	.04	45.95	4.98	50.97	8.41	10.40
Percentage of total accretion or depletion	*Percent* 81.25	*Percent* 18.75	*Percent* 100.00	*Percent* .08	*Percent* 90.15	*Percent* 9.77	*Percent* 100.00	--------	--------
1947—Meadow:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	5.28	[1] 1.05	6.33	0	[1] 2.07	3.32	5.39	0.94	--------
February	1.12	[1] 1.53	2.65	.02	[1] 2.19	.28	2.49	.16	--------
March	2.30	1.07	3.37	.03	2.93	.58	3.54	--------	0.17
April	4.43	.82	5.25	0	3.20	1.90	5.10	.15	--------
May	6.44	.65	7.09	.01	4.76	2.66	7.43	--------	.34
June	5.79	.45	6.24	.02	6.90	1.11	8.03	--------	1.79
July	3.03	.45	3.48	.01	5.60	.05	5.66	--------	2.18
August	3.70	.63	4.33	.02	4.69	.03	4.74	--------	.41
September	3.18	.45	3.63	0	5.13	.02	5.15	--------	1.52
October	1.21	.76	1.97	0	3.07	.01	3.08	--------	1.11
November	2.74	.76	3.50	0	1.49	.01	1.50	2.00	--------
December	1.52	.99	2.51	0	1.37	0	1.37	1.14	--------
Total	40.74	9.61	50.35	.11	43.40	9.97	53.48	4.39	7.52
Percentage of total accretion or depletion	*Percent* 80.91	*Percent* 19.09	*Percent* 100.00	*Percent* .21	*Percent* 81.15	*Percent* 18.64	*Percent* 100.00	--------	--------

See footnote at end of table.

TABLE 7.—*Monthly summary of the accretion, depletion, and storage of soil water as determined by the weighing monolith lysimeter Y103A, 1944–55*—Continued

Year, month, and crop grown	Accretion			Depletion				Storage in 8-foot profile	
	Precipitation	Condensation	Total	Runoff	Evapotranspiration	Percolation	Total	Net increase	Net decrease
1948—Meadow:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	3.12	[1] 1.27	4.39	0	[1] 1.58	0.01	1.59	2.80	
February	3.23	[1] 1.43	4.66	0	[1] 2.31	1.54	3.85	.81	
March	4.96	1.26	6.22	.02	3.24	2.19	5.45	.77	
April	4.89	.54	5.43	.02	4.57	2.42	7.01		1.58
May	3.81	.34	4.15	.01	6.88	.10	6.99		2.84
June	5.39	.31	5.70	.02	7.57	.02	7.61		1.91
July	3.56	.44	4.00	.01	6.09	.01	6.11		2.11
August	.99	.51	1.50	0	3.65	.01	3.66		2.16
September	3.91	.45	4.36	.01	3.28	0	3.29	1.07	
October	2.72	.63	3.35	.01	2.34	0	2.35	1.00	
November	3.00	.83	3.83	0	1.71	0	1.71	2.12	
December	2.37	1.04	3.41	0	1.45	0	1.45	1.96	
Total	41.95	9.05	51.00	.10	44.67	6.30	51.07	10.53	10.60
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		
Percentage of total accretion or depletion	82.25	17.75	100.00	.19	87.47	12.34	100.00		
1949—Corn:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	5.49	[1] 1.05	6.54	0	1.84	1.96	3.80	2.74	
February	2.87	[1] 1.15	4.02	.01	2.20	1.59	3.80	.22	
March	3.95	1.41	5.36	0	3.30	1.42	4.72	.64	
April	2.98	.64	3.62	0	3.88	.37	4.25		0.63
May	3.04	.85	3.89	.02	4.62	.14	4.78		.89
June	3.40	.69	4.09	.01	5.92	.01	5.94		1.85
July	8.90	.28	9.18	.19	8.83	.05	9.07	.11	
August	2.75	.70	3.45	.01	5.82	0	5.83		2.38
September	3.43	1.13	4.56	0	3.25	0	3.25	1.31	
October	1.04	1.27	2.31	0	2.68	0	2.68		.37
November	1.59	.97	2.56	0	2.10	0	2.10	.46	
December	3.01	1.70	4.71	.01	2.35	0	2.36	2.35	

Total	42.45	11.84	54.29	.25	46.79	5.54	52.58	7.83	6.12
Percentage of total accretion or depletion	*Percent* 78.19	*Percent* 21.81	*Percent* 100.00	*Percent* .47	*Percent* 88.99	*Percent* 10.54	*Percent* 100.00		
1950—Wheat:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	8.59	1.40	9.99	0.03	2.58	4.76	7.37	2.62	
February	3.59	[1] 1.84	5.43	.01	[1] 2.76	2.21	4.98	.45	
March	2.94	[1] 1.88	4.82	0	[1] 3.84	1.25	5.09		.27
April	4.54	1.30	5.84	.01	3.85	1.63	5.49	.35	
May	4.70	.50	5.20	.01	6.61	.13	6.75		1.55
June	2.03	.60	2.63	0	6.45	.04	6.49		3.86
July	6.66	1.00	7.66	.01	4.73	.02	4.76	2.90	
August	2.12	.95	3.07	0	5.80	.02	5.82		2.75
September	5.58	.68	6.26	.01	4.44	.04	4.49	1.77	
October	1.58	.80	2.38	0	3.37	.02	3.39		1.01
November	6.23	[1] .75	6.98	0	[1] 2.22	.09	2.31	4.67	
December	3.41	[1] 1.15	4.56	.01	[1] 2.66	2.67	5.34		.78
Total	51.97	12.85	64.82	.09	49.31	12.88	62.28	12.76	10.22
Percentage of total accretion or depletion	*Percent* 80.18	*Percent* 19.82	*Percent* 100.00	*Percent* .15	*Percent* 79.17	*Percent* 20.68	*Percent* 100.00		
1951—Meadow:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	5.65	[1] 1.14	6.79	0.04	[1] 2.48	3.62	6.14	0.65	
February	4.30	[1] 4.26	8.56	.12	[1] 6.12	3.47	9.71		1.15
March	5.71	[1] 1.71	7.42	.03	[1] 3.66	3.30	6.99	.43	
April	3.58	1.26	4.84	.01	3.48	1.91	5.40		.56
May	2.62	.65	3.27	.01	6.38	.17	6.56		3.29
June	5.81	.65	6.46	.02	5.87	.06	5.95	.51	
July	3.04	.55	3.59	.02	7.28	.03	7.33		3.74
August	.75	1.39	2.14	0	3.66	.02	3.68		1.54
September	3.12	.75	3.87	.01	3.76	.01	3.78	.09	
October	1.94	.79	2.73	0	2.99	.01	3.00		.27
November	5.04	[1] .85	5.89	0	[1] 1.62	.01	1.63	4.26	
December	5.92	[1] 2.68	8.60	.01	[1] 4.23	1.09	5.33	3.27	
Total	47.48	16.68	64.16	.27	51.53	13.70	65.50	9.21	10.55
Percentage of total accretion or depletion	*Percent* 74.00	*Percent* 26.00	*Percent* 100.00	*Percent* .41	*Percent* 78.67	*Percent* 20.92	*Percent* 100.00		

See footnote at end of table.

TABLE 7.—*Monthly summary of the accretion, depletion, and storage of soil water as determined by the weighing monolith lysimeter Y103A, 1944–55*—Continued

Year, month, and crop grown	Accretion			Depletion				Storage in 8-foot profile	
	Precipitation	Condensation	Total	Runoff	Evapotranspiration	Percolation	Total	Net increase	Net decrease
1952 Meadow:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	5.54	[1] 1.48	7.02	0.03	[1] 2.80	3.65	6.48	0.54	-----
February	3.02	[1] 1.37	4.39	.02	[1] 2.70	1.86	4.58	-----	0.19
March	4.02	[1] 1.53	5.55	.03	[1] 3.39	1.92	5.34	.21	-----
April	4.39	.75	5.14	.02	4.27	1.58	5.87	-----	.73
May	4.42	.50	4.92	0	6.57	.07	6.64	-----	1.72
June	2.79	.37	3.16	.02	5.56	.02	5.60	-----	2.44
July	4.15	.34	4.49	.02	6.70	.02	6.74	-----	2.25
August	2.12	.52	2.64	.01	4.38	.01	4.40	-----	1.76
September	2.59	.62	3.21	.01	3.67	0	3.68	-----	.47
October	.78	1.03	1.81	0	2.16	0	2.16	-----	.35
November	1.94	[1] 1.22	3.16	.01	[1] 1.95	0	1.96	1.20	-----
December	2.73	[1] 1.08	3.81	.01	[1] 1.59	.01	1.61	2.20	-----
Total	38.49	10.81	49.30	.18	45.74	9.14	55.06	4.15	9.91
Percentage of total accretion or depletion	*Percent* 78.07	*Percent* 21.93	*Percent* 100.00	*Percent* .33	*Percent* 83.07	*Percent* 16.60	*Percent* 100.00	-----	-----
1953 Corn:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	5.64	[1] 0.97	6.61	0.02	[1] 1.77	0.18	1.97	4.64	-----
February	1.49	[1] 1.32	2.81	0	[1] 2.19	.34	2.53	.28	-----
March	3.48	[1] 1.08	4.56	.01	[1] 2.72	.98	3.71	.85	-----
April	2.87	.87	3.74	0	3.58	.50	4.08	-----	0.34
May	4.20	.75	4.95	.02	5.10	.42	5.54	-----	.59
June	2.69	.74	3.43	.02	4.95	.02	4.99	-----	1.56
July	5.20	.37	5.57	0	7.71	.01	7.72	-----	2.15
August	1.74	.76	2.50	.01	5.40	.01	5.42	-----	2.92
September	1.18	1.24	2.42	0	2.62	0	2.62	-----	.20
October	.72	1.56	2.28	0	2.21	.01	2.22	.06	-----
November	1.35	[1] 1.13	2.48	0	[1] 1.57	.01	1.58	.90	-----
December	2.63	[1] 1.03	3.66	.02	[1] 2.05	.02	2.09	1.57	-----

Total	33.10	11.82	15.01	.10	41.87	2.50	44.47	8.30	7.76
Percentage of total accretion or depletion	*Percent* 73.74	*Percent* 26.26	*Percent* 100.00	*Percent* .23	*Percent* 94.15	*Percent* 5.62	*Percent* 100.00	--------	--------
1954 Wheat:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	2.90	[1] 1.03	3.99	0.11	[1] 1.73	0.04	1.88	2.11	--------
February	2.17	[1] 1.04	3.21	.02	[1] 2.03	.01	2.06	1.15	--------
March	5.12	[1] 1.28	6.40	.08	[1] 3.98	.24	4.30	2.10	--------
April	3.29	.94	4.23	.07	4.20	.26	4.53	--------	0.30
May	2.40	.44	2.84	0	6.50	.05	6.64	--------	3.80
June	2.09	.41	2.50	.01	5.74	.01	5.76	--------	3.26
July	3.37	1.04	4.41	.01	3.42	.01	3.44	.97	--------
August	3.49	.68	4.17	.01	4.90	.01	4.92	--------	.75
September	1.43	1.21	2.64	0	3.07	0	3.07	--------	.43
October	5.94	.82	6.76	.02	2.58	0	2.60	4.16	--------
November	1.58	[1] 1.21	2.79	0	[1] 2.14	0	2.14	.65	--------
December	2.82	[1] 1.22	4.04	0	[1] 1.64	.01	1.65	2.39	--------
Total	36.66	11.32	47.98	.33	42.02	.64	42.99	13.53	8.54
Percentage of total accretion or depletion	*Percent* 76.41	*Percent* 23.59	*Percent* 100.00	*Percent* .77	*Percent* 97.74	*Percent* 1.49	*Percent* 100.00	--------	--------
1955 - Meadow:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*		
January	2.15	[1] 1.07	3.22	0	[1] 1.66	0.08	1.74	1.48	--------
February	3.87	[1] 1.70	5.57	.02	[1] 3.13	1.93	5.08	.49	--------
March	5.13	[1] 1.62	6.75	.02	[1] 4.02	2.68	6.72	.03	--------
April	3.97	.88	4.85	0	5.11	.35	5.46	--------	0.61
May	1.82	.38	2.20	0	7.48	.11	7.59	--------	5.39
June	3.14	.82	3.96	0	4.85	.03	4.88	--------	.02
July	3.45	.81	4.26	.01	5.42	.02	5.45	--------	1.19
August	3.53	.65	4.18	.01	5.33	.01	5.35	--------	1.17
September	2.43	1.12	3.55	0	3.69	.01	3.70	--------	.15
October	2.42	.85	3.27	0	3.37	.01	3.38	--------	.11
November	3.60	[1] 1.02	4.62	0	[1] 1.87	.02	1.89	2.73	--------
December	.39	[1] 1.32	1.71	0	[1] 1.67	.02	1.69	.02	--------
Total	35.90	12.24	48.14	.06	47.60	5.27	52.93	4.75	9.54
Percentage of total accretion or depletion	*Percent* 74.57	*Percent* 25.43	*Percent* 100.00	*Percent* .11	*Percent* 89.93	*Percent* 9.96	*Percent* 100.00	--------	--------

[1] Some snowfall during the month; values may be too high because of drifting of snow.

of soil moisture, when summarized separately in terms of CA and ET, provided an evaluation of each of these moisture-change factors. The net soil-moisture change (ET—CA), however, will probably prove to be a more useful value in the general field of agricultural hydrology.

Accretion

The weighing lysimeters acquired moisture through precipitation, sprinkler irrigation, condensation, and absorption. Precipitation was mainly in the form of rain, but snow, sleet, and hail were also included in the measurements. The precipitation data derived from lysimeter weight records represent the amounts falling to the earth's surface as contrasted with data obtained by the ordinary rain and snow gages. The latter are known to be inadequate during windy periods.

Condensation was mainly the water converted from vapor form in the atmosphere to liquid on the vegetation or soil surface. It includes also the moisture absorbed by the soil from vapor in the air layers near the ground surface and the water condensed from vapor in the soil pores. Condensation of vapor within the soil, resulting from soil-temperature fluctuations, accounted for only a very small part (less than 1 percent) of the total condensation. As soon as the vapor became liquid on the vegetation or in the soil of the lysimeters, its weight was recorded. Well-defined weight increases during periods of no precipitation were attributed to condensation-absorption.

Overall weight increases were tabulated for each daily accretion period and converted to inches of water. Plus and minus variations in weight within periods of general weight increase were omitted in the calculations. Thus, the CA values are only net increases and, therefore, are minimum values. If all the minor increases were totaled for each day, the resultant CA values would be greater than those given herein. Furthermore, whenever transpiration occurs during the CA period, only the net weight change can be measured. If it were possible to evaluate these two separately, the resultant values of ET and CA would be greater than those presented herein. These records made it possible to determine the hours of condensation-absorption and its fluctuation by seasons with different vegetal covers. Only monthly and annual values are given in tables 5, 6, and 7.

Precipitation was a greater accretion factor by far than condensation and absorption combined, averaging about 80 percent of the total accretion. Generally, this percentage was lower during the drier years and higher during the years when precipitation was above normal. However, an appreciable amount of moisture other than precipitation was supplied to the soil and its plant cover through condensation-absorption. This averaged about 20 percent of the total accretion and was higher during the drier years. Actual amounts ranged from 6 to 9 inches of water annually. Values much greater than these (tables 5, 6, and 7) are somewhat abnormal because of drifting snow. During the winter the drifting of snow off and on the lysimeters is variable and the values for evapotranspiration and condensation-absorption, which are based on actual lysimeter weights, are necessarily incorrect. When this occurred, the monthly values are footnoted. Annual values of CA that include one or more footnoted values are greater than true CA values.

The monthly values of condensation-absorption, when drifting snow had no effect, ranged from 0.07 to 1.56 inches and averaged about 0.5 to 0.6 inch per month. Although much of this water was removed by evaporation after a few hours of sunshine, the data indicate that dew has some moisture-conservation value. This is described in detail in a later section of this report.

It is interesting to note that in some months of very small rainfall during the growing season, CA values contribute greatly to the total moisture accretion for the month. For example, rainfall on lysimeter Y101D in August 1945 (table 5) totaled 0.94 inch, and CA amounted to 0.56 inch, or 37 percent of the total accretion for August. In September 1946 on the same lysimeter CA was 0.90 inch, or 48 percent of the total accretion. CA and rainfall were nearly equal. Apparently a small amount of rainfall and high rates of moisture extraction resulted in a dry soil, which in turn was conducive to high values of CA.

Depletion

Of the three depletion factors evapotranspiration, percolation, and runoff evapotranspiration, in general, accounted for the most depletion and runoff the least. During many summer months evapotranspiration was greater than rainfall. During March and April, percolation values often exceed evapotranspiration values. ET values given herein do not represent the daily, monthly, or annual rate of soil-moisture depletion. If such data are desired, ET—CA values should be used. For example, in May 1954, ET on Y101D (table 5) was 6.16 inches. However, CA for the same month was 0.78 inch and the net depletion of soil moisture was 6.16—0.78 (ET—CA), or 5.38 inches. As rain for the month totaled 2.44 inches, actual storage change was 5.38—2.44, or 2.94 inches. ET—CA is generally referred to as "consumptive use" of water by vegetation.

Annual evapotranspiration values ranged from 31.22 to 49.42 inches on Y101; from 34.49 to 49.12 inches on Y102; and from 36.17 to 51.53 inches on Y103. Evapotranspiration was lower in the dry year 1944 than in other years. It constituted about 80 percent of the total annual depletion on the Muskingum soils and about 87 percent on the Keene silt loam. In the dry years 1953 and 1954, however, both the amount of ET and the percentage of depletion was considerably higher on Y101D, amounting to over 96 percent in 1953 and nearly 100 percent in 1954. This difference resulted largely from the influence of vegetative cover since poverty grass, with its very shallow root system, removed less water by transpiration in 1944 than the deeper rooted alfalfa-bromegrass, which was the dominant vegetation on lysimeter Y101D after 1947. Alfalfa-bromegrass consumed so much water that only 1.53 inches was available for percolation in 1953 and none in 1954. Evapotranspiration in 1954 amounted to over 99 percent of the total depletion.

More water was removed from the soil by evapotranspiration in May, June, July, and August than in other months. Higher temperatures and longer days were conducive to higher ET values. Conditions favorable to vegetative growth increased evapotranspiration. The stage of growth of a crop, that is, the extent of leaf-area development and maturity, also affected evapotranspiration. For example, on Y102C, the evapotranspiration value for corn in May 1953 was over 1.5 inches lower than for meadow in May 1952. The May rainfall was nearly the same both years. But the small leaf area of the corn plants removed little soil water by transpiration in

1953; water loss was mainly in the form of evaporation. On the contrary, leaf area of the meadow covered the ground completely in May 1952, and water loss was mostly by transpiration.

The net loss to soil moisture is properly represented by evapotranspiration minus condensation-absorption. This is referred to as ET—CA, curves of which are shown in figures 6 to 17 for various lysimeter crops. No effort has been made to separate evapotranspiration into its component parts since the combined values provide the necessary information for hydrologic studies.

The effect of irrigation on ET can be observed from data for 1953, 1954, and 1955 in tables 6 and 7. ET values for Y102C prior to irrigation in 1953 were less than for unirrigated Y103A. After irrigation, ET values for Y102C exceeded values for unirrigated Y103A for several months. This same relationship prevailed in 1954 and 1955.

Soil-Moisture Storage Changes

The weighing lysimeter, by automatically recording the weights at 10-minute intervals, indicated whether soil-moisture storage was accumulating or depleting for any period of the day. As shown in tables 5, 6, and 7, the lysimeters gained weight through increases in soil moisture in some seasons and lost moisture more rapidly than it was received in other seasons. The monthly values from April to September generally showed losses of moisture in storage, although April and September showed gains in some years. When precipitation for any of these months was unusually high, a gain in storage resulted. The other months (October to March) generally showed a gain in storage unless precipitation was well below normal.

The net annual storage-change values varied from year to year. In the wet years 1945 and 1950, there was a net increase in storage. High monthly rainfall, however, did not always result in an increase in moisture storage. For example, more than 9 inches of rain fell on the very wet soil of Y102C in March 1945, yet the monthly net storage decreased 0.89 inch, principally because of excessive percolation.

In September of the same year over 9 inches of rain fell on the same lysimeter, but the soil profile was far from saturated. There was no percolation. Although runoff of 2.03 inches reduced the accretion value of the rain, net storage increased 4.79 inches for the month. On lysimeter Y103A, there was practically no runoff and the storage increase was greater, amounting to 6.58 inches for the month.

Storage of moisture in the lysimeters in 1 year ranged from a maximum gain of over 6 inches to a maximum loss of over 6 inches (table 8). The greatest loss in storage occurred in 1952, the first year of drought. Total precipitation in 1952 was about normal, but for the last 5 months of the year it was very deficient. The normal recharge of soil moisture in the fall and early winter months was missing and 1953 started with low soil-moisture storage.

Precipitation in 1953 was nearly 10 inches below normal. Net storage change for that year on Y101D was a loss of 2.79 inches, caused by the extraction of moisture by deep-rooted alfalfa and bromegrass. Net storage change on Y103A was a gain of 0.54 inch. It was just about as dry at the end of the year as at the beginning. Net storage change on Y102C was a gain of 4.70 inches, mostly as a result of irrigation of 8.07 inches.

Moisture-storage increase was highest in 1953 on Y102C. In 1954 it was not nearly as much as on

TABLE 8.—*Annual net gain or loss in soil moisture for lysimeters Y101D, Y102C, and Y103A, 1944–55 (inches of water)*

Year	Y101D		Y102C		Y103A	
	Gain	Loss	Gain	Loss	Gain	Loss
1944		0.35	2.39			0.42
1945	4.31		1.85		3.69	
1946		.56		0.53		1.99
1947		4.67		5.69		3.13
1948	.36		.54			.07
1949		1.78	2.66		1.71	
1950	6.05		3.27		2.54	
1951		2.71		1.52		1.34
1952		4.52		6.71		5.76
1953		2.79	4.70		.54	
1954	4.67		1.64		4.99	
1955	1.13			5.37		4.79
Total	16.52	17.38	17.05	19.82	13.47	17.50
Net		.86		2.77		4.03

Y101D and Y103A. The overall change in moisture storage for the 12-year period was −0.86 inch on Y101D, −2.77 inches on Y102C, and −4.03 inches on Y103A.

Figures 6 to 17 show cumulative rainfall, runoff, percolation, and ET—CA for 1944–55. Daily changes in soil-moisture storage for the 0- to 40-inch profile are also given for these years. This 40-inch layer includes practically all the roots of plants grown in the 4-year crop-rotation system. On the permanent grass lysimeters, it is likely the roots did not penetrate below this 40-inch depth except when it was alfalfa-bromegrass.

The top curve of soil moisture represents the conditions on the Keene silt loam of Y103A. This is natural, as the Muskingum soil of Y101D and Y102C is lighter textured and holds less water. There are times when the soil-moisture curves for Y101D and Y102C are almost identical, as in 1945 (fig. 7), 1946 (fig. 8), 1947 (fig. 9), and 1948 (fig. 10). A new seeding of alfalfa-bromegrass was made on Y101D in April 1947 (Appendix) and soil moisture from that time to October was at a higher level than on Y102C. In 1949 the soil-moisture curves for these two lysimeters are identical until May. During May and June they separate, with the curve for Y101D dropping much more rapidly. This is as it should be; the grass on Y102C was spaded, and corn was planted in early May and consequently very little water was consumed by the small corn plants until July.

Another interesting separation of moisture curves occurred in July 1950 (fig. 12). After wheat harvest on Y102C, the soil surface was chopped and a new meadow was seeded on August 4 because of failure of the meadow seeded in the wheat in March. In July the soil surface on Y102C was fallow whereas Y101D was in alfalfa-bromegrass, and the depletion of soil moisture on the latter was more than 4 inches greater than on Y102C.

Alfalfa-bromegrass on Y101D showed a more rapid use of water than the first-year meadow on Y102C in May and August 1951 (fig. 13). The difference was not apparent in 1952 when Y102C was in second-year alfalfa-timothy meadow (fig. 14).

The separation of soil-moisture curves for Y101D and Y102C in

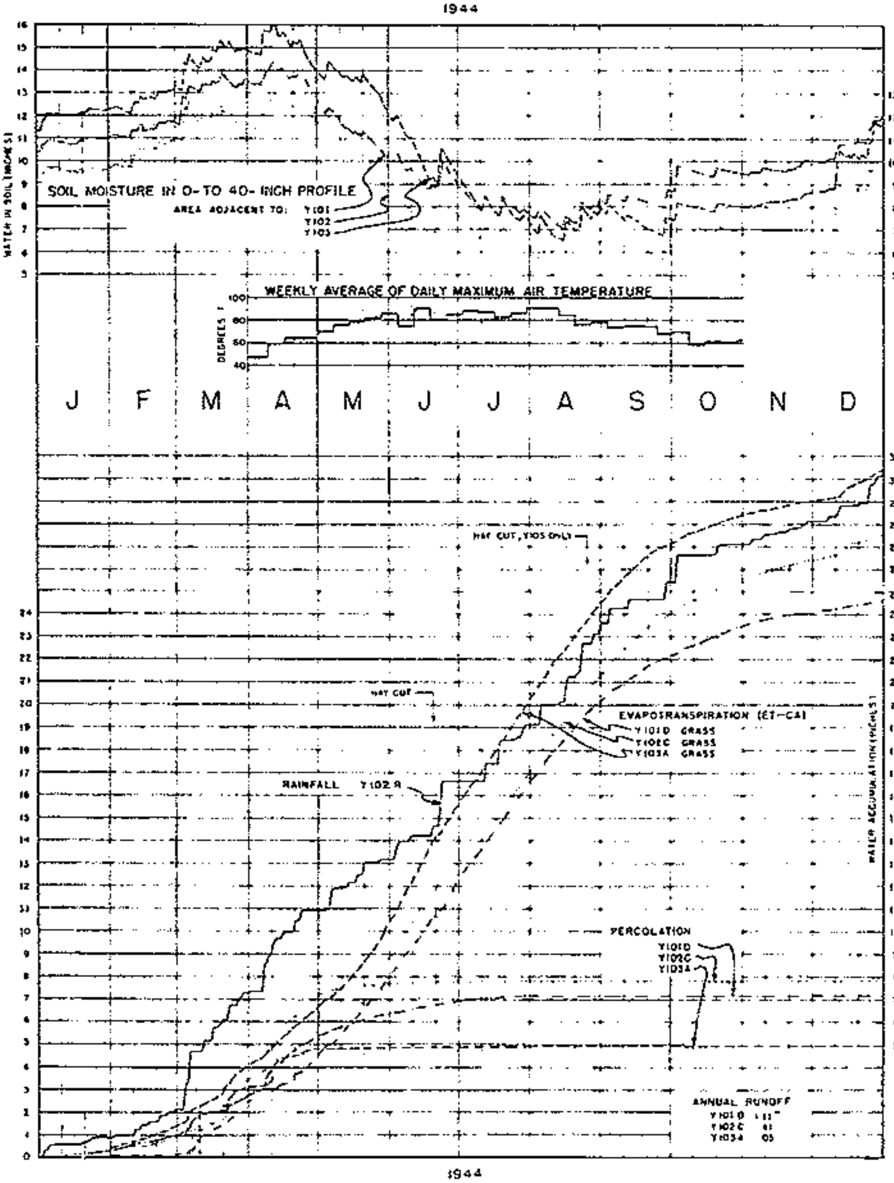

FIGURE 6.—Daily soil moisture, accumulated daily precipitation, evapotranspiration (ET—CA), percolation, and weekly average air temperature, lysimeters Y101D, Y102C, and Y103A, 1944.

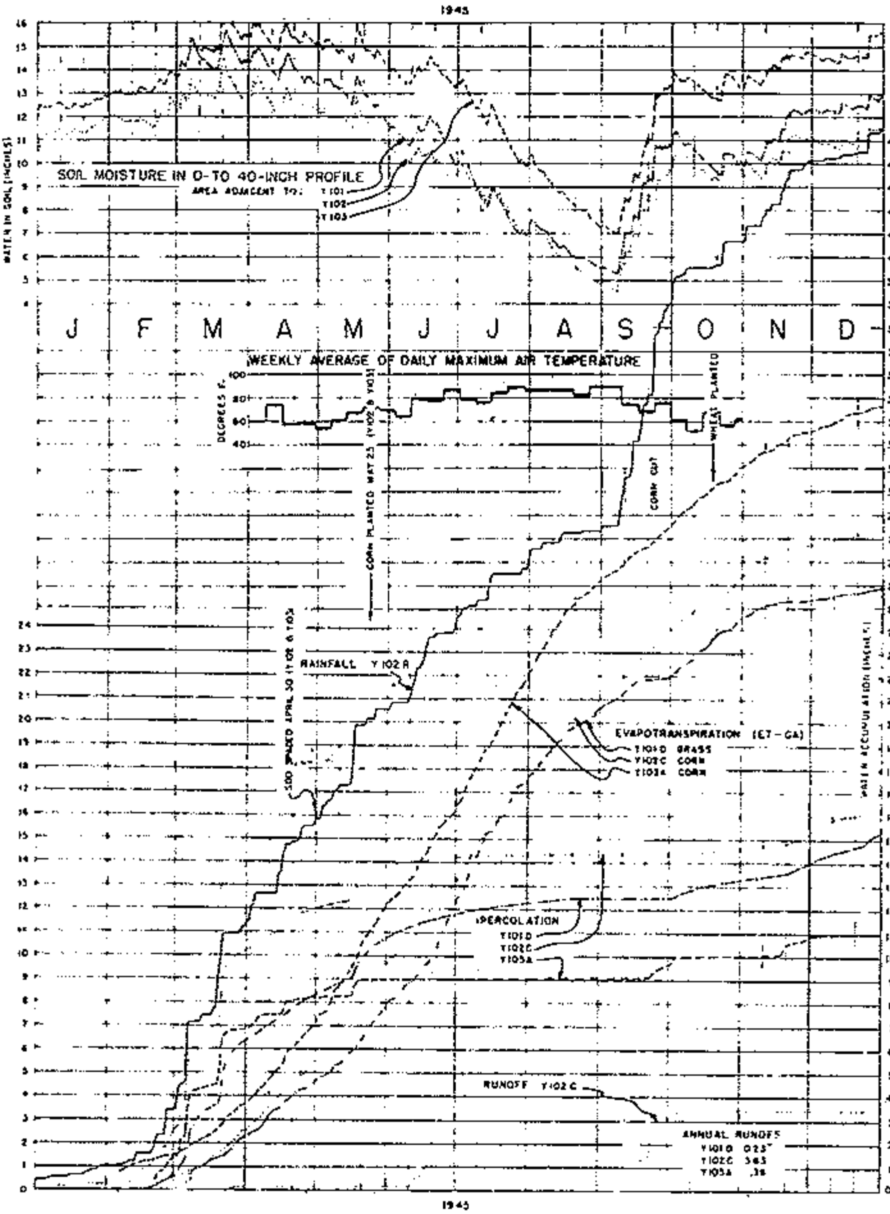

FIGURE 7. Daily soil moisture, accumulated daily precipitation, evapotranspiration (ET–CA), percolation, and weekly average air temperature, lysimeters Y101D, Y102C, and Y103A, 1945.

May and June 1953 (fig. 15) was much the same as in 1949 (fig. 11). Irrigation on Y102C in 1953 brought its moisture curve up above that for Y103A. The curve for Y101D shows a low point of about 1 inch of water in 40 inches of soil. All values below 4 inches are

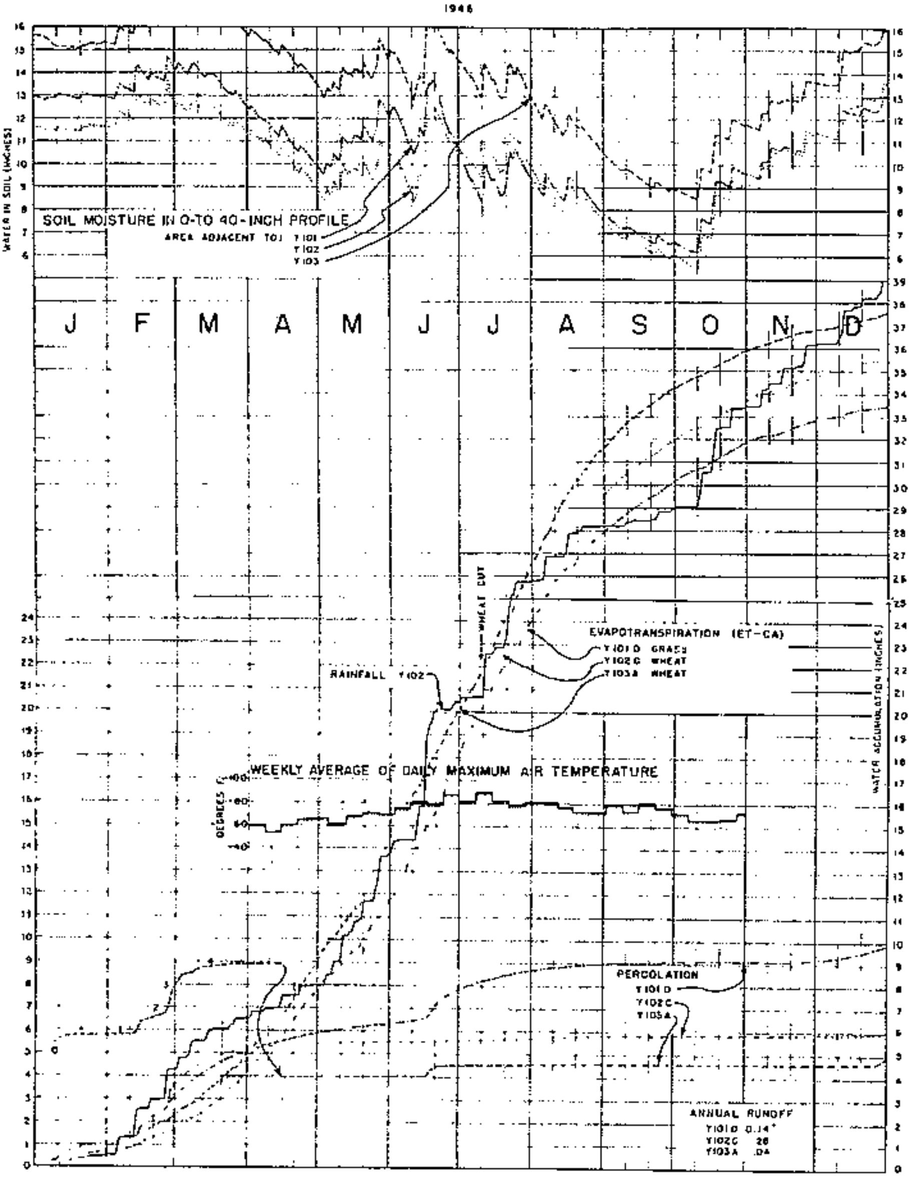

FIGURE 8.—Daily soil moisture, accumulated daily precipitation, evapotranspiration (ET—CA), percolation, and weekly average air temperature, lysimeters Y101D, Y102C, and Y103A, 1946.

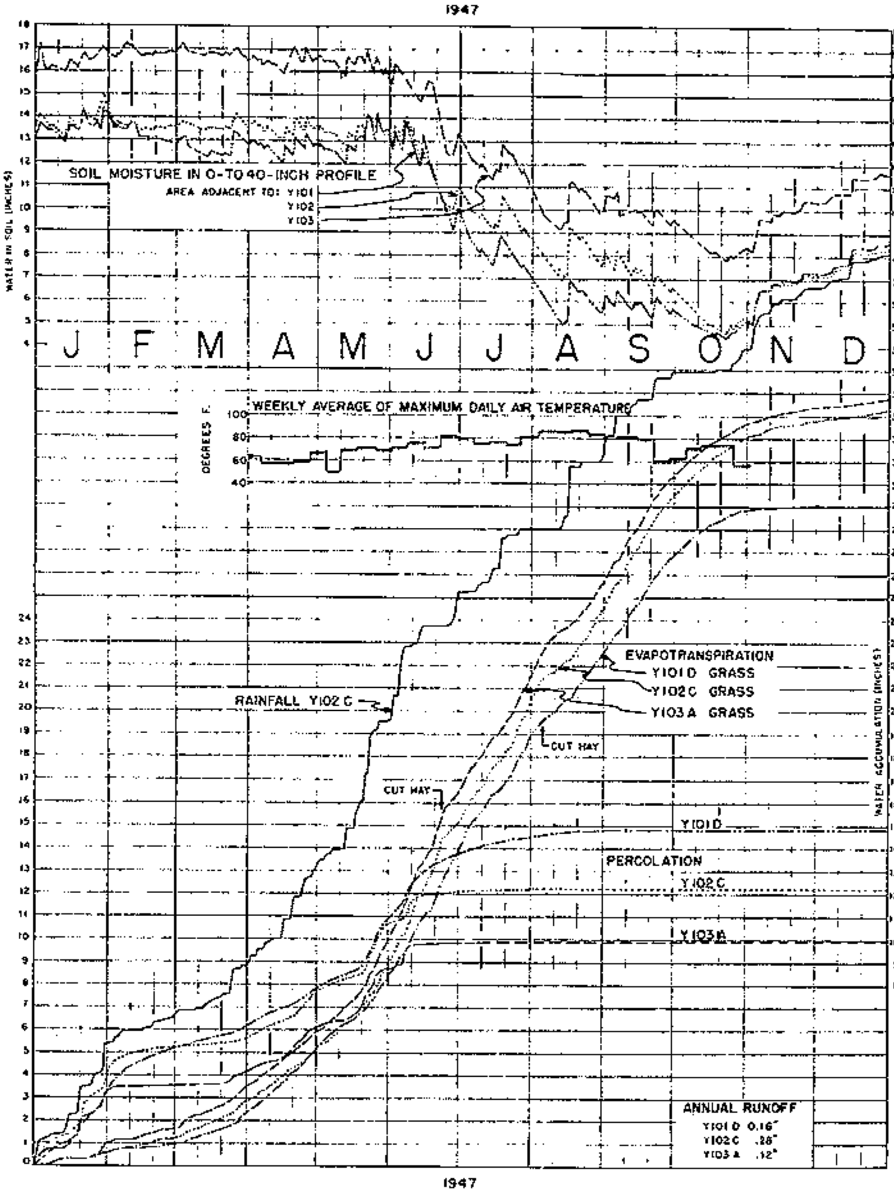

FIGURE 9.—Daily soil moisture, accumulated daily precipitation, evapotranspiration (ET—CA), percolation, and weekly average air temperature, lysimeters Y101D, Y102C, and Y103A, 1947.

probably fictitious. All the moisture extracted by the alfalfa-bromegrass was attributed to the 40-inch profile, whereas it is probable that much of the moisture used in late August and September came from below the 40-inch depth. Methods of computation of soil-moisture

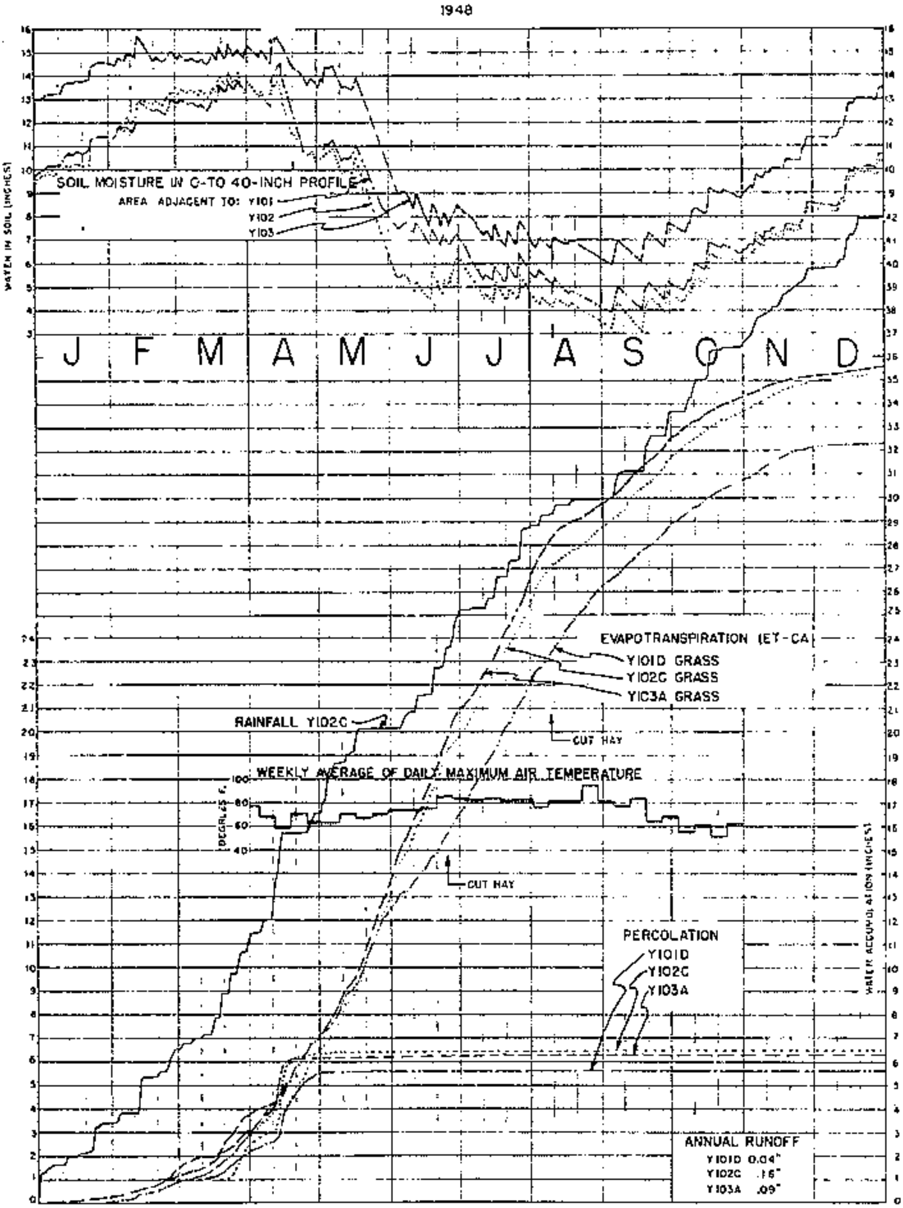

FIGURE 10.—Daily soil moisture, accumulated daily precipitation, evapotranspiration (ET—CA), percolation, and weekly average air temperature, lysimeters Y101D, Y102C, and Y103A, 1948.

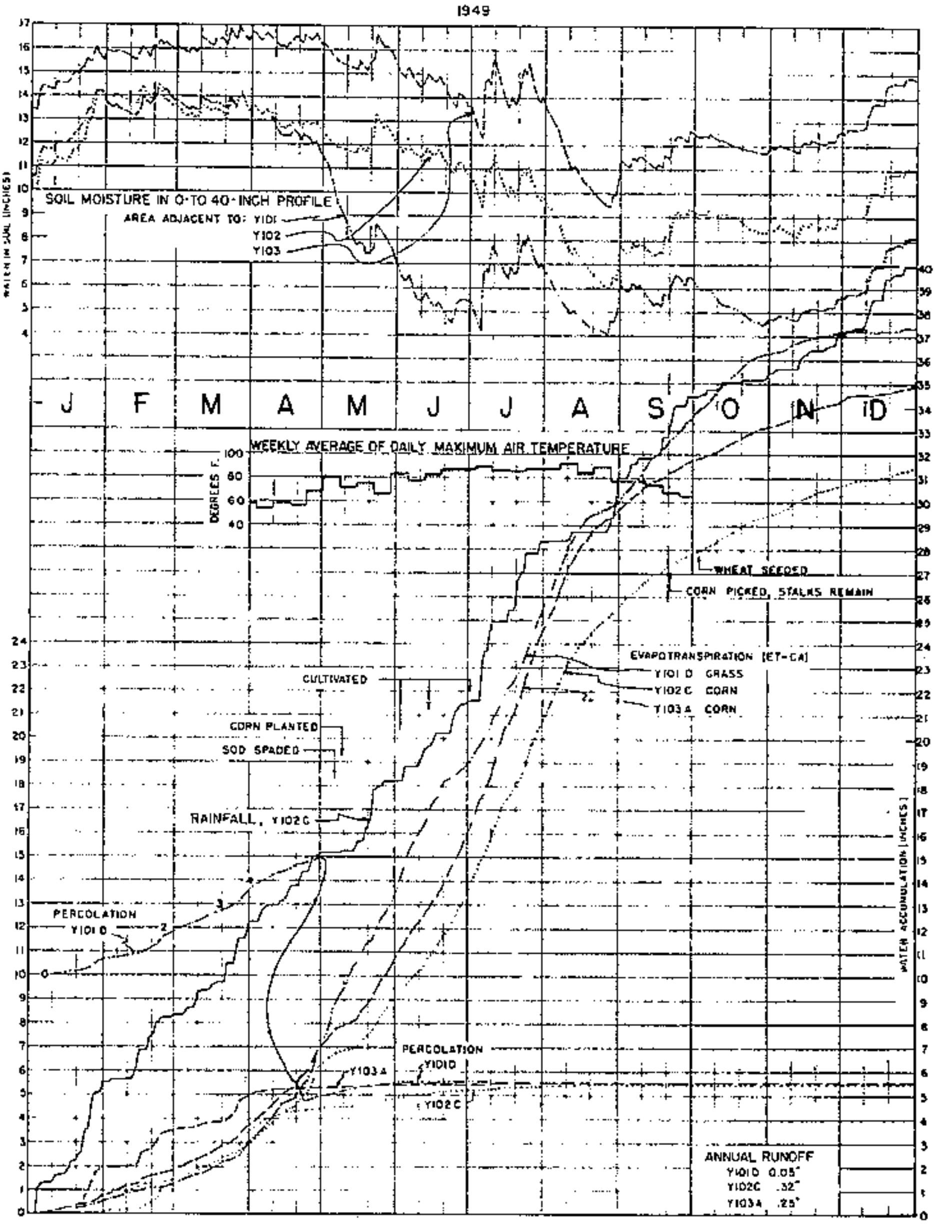

FIGURE 11.—Daily soil moisture, accumulated daily precipitation, evapotranspiration (ET—CA), percolation, and weekly average air temperature, lysimeters Y101D, Y102C, and Y103A, 1949.

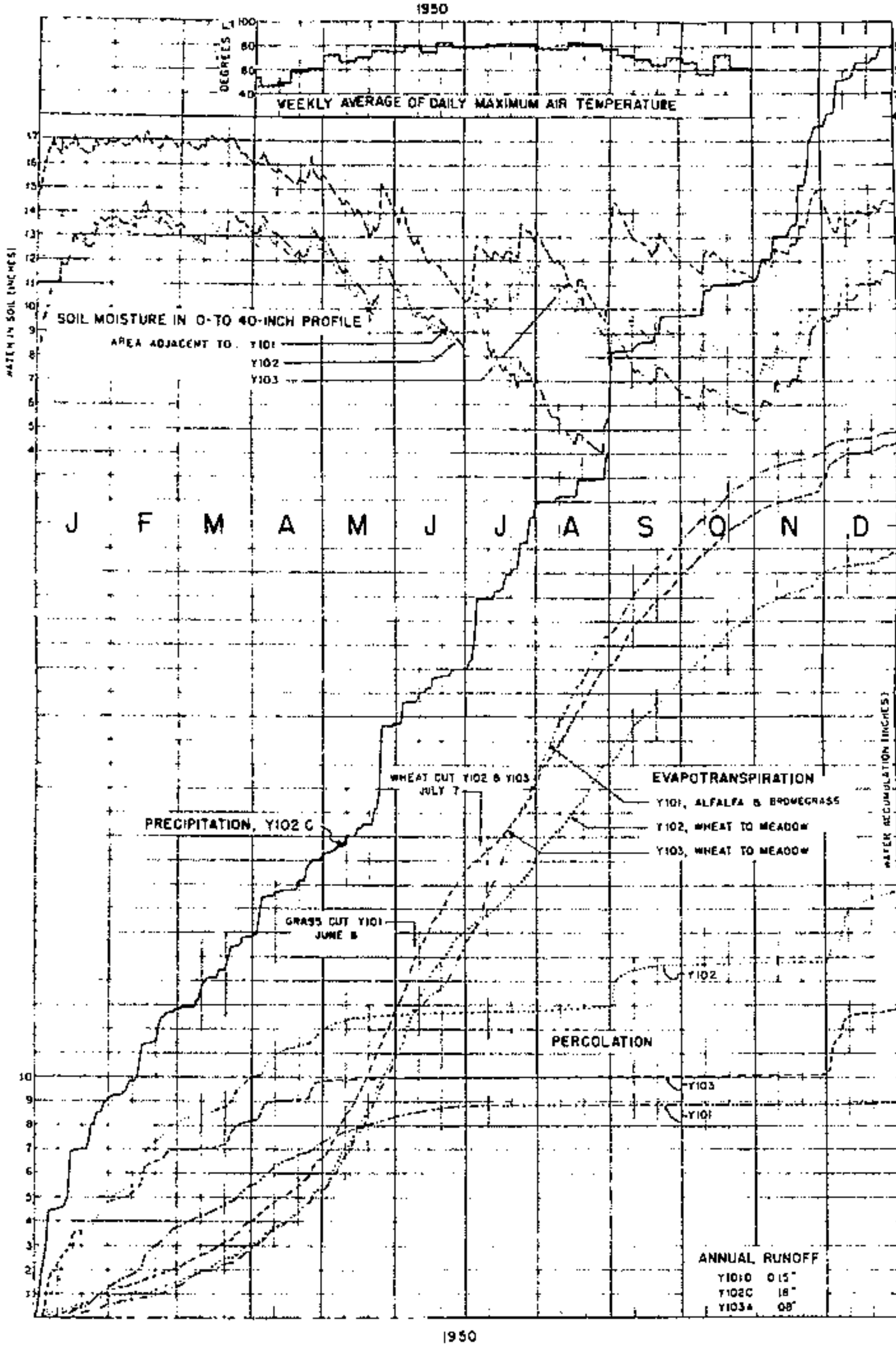

FIGURE 12.—Daily soil moisture, accumulated daily precipitation, evapotranspiration (ET—CA), percolation, and weekly average air temperature, lysimeters Y101D, Y102C, and Y103A, 1950.

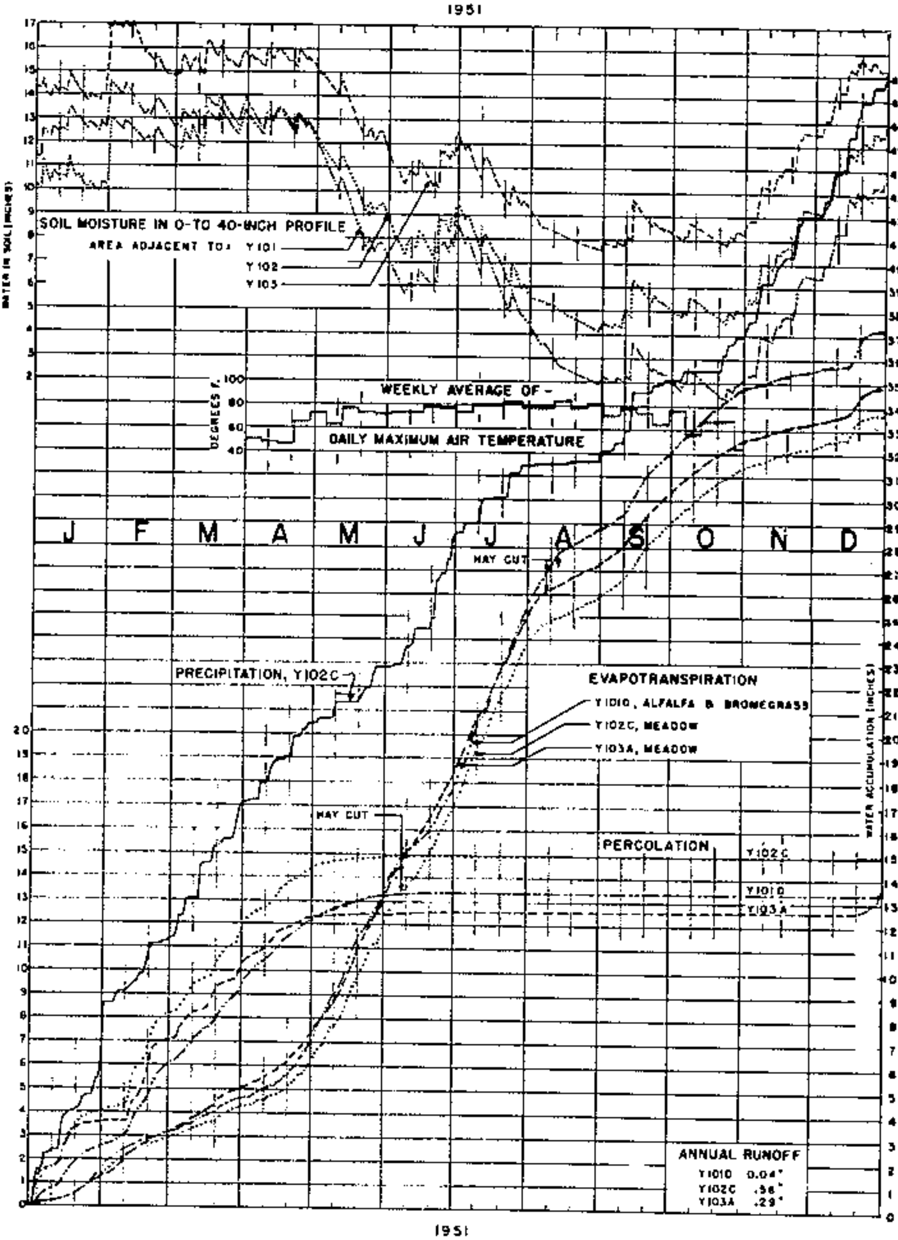

FIGURE 13. Daily soil moisture, accumulated daily precipitation, evapotranspiration (ET—CA), percolation, and weekly average air temperature, lysimeters Y101D, Y102C, and Y103A, 1951.

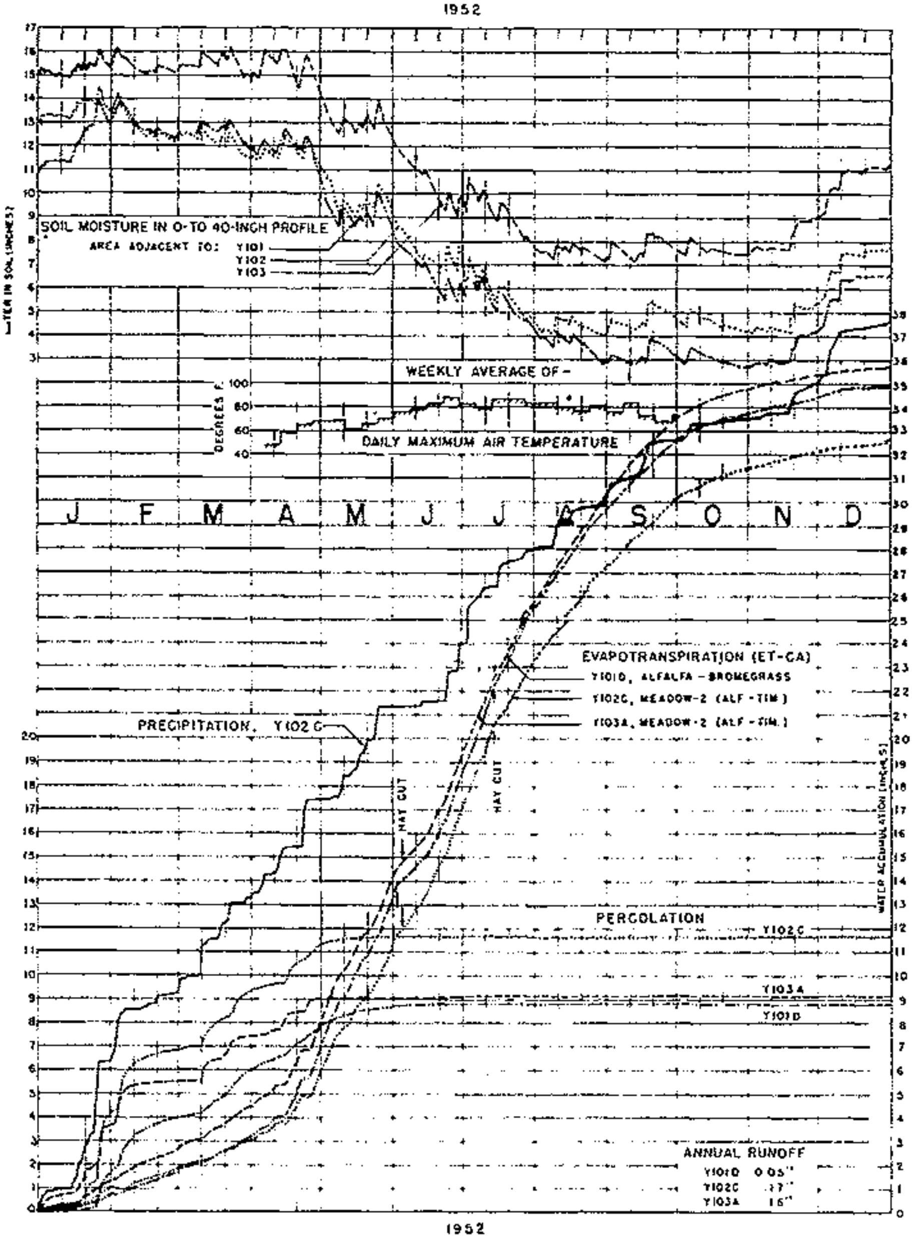

FIGURE 14. Daily soil moisture, accumulated daily precipitation, evapotranspiration (ET - CA), percolation, and weekly average air temperature, lysimeters Y101D, Y102C, and Y103A, 1952.

changes did not allow for this condition. This also applies to the low portion of the soil-moisture curve for Y101D in 1954 (fig. 16).

The wide separation of the soil-moisture curves for Y101D and Y102C in late 1953 diminished during the winter and spring recharge period (fig. 15) and was eliminated by May 1954 (fig. 16). In July 1954

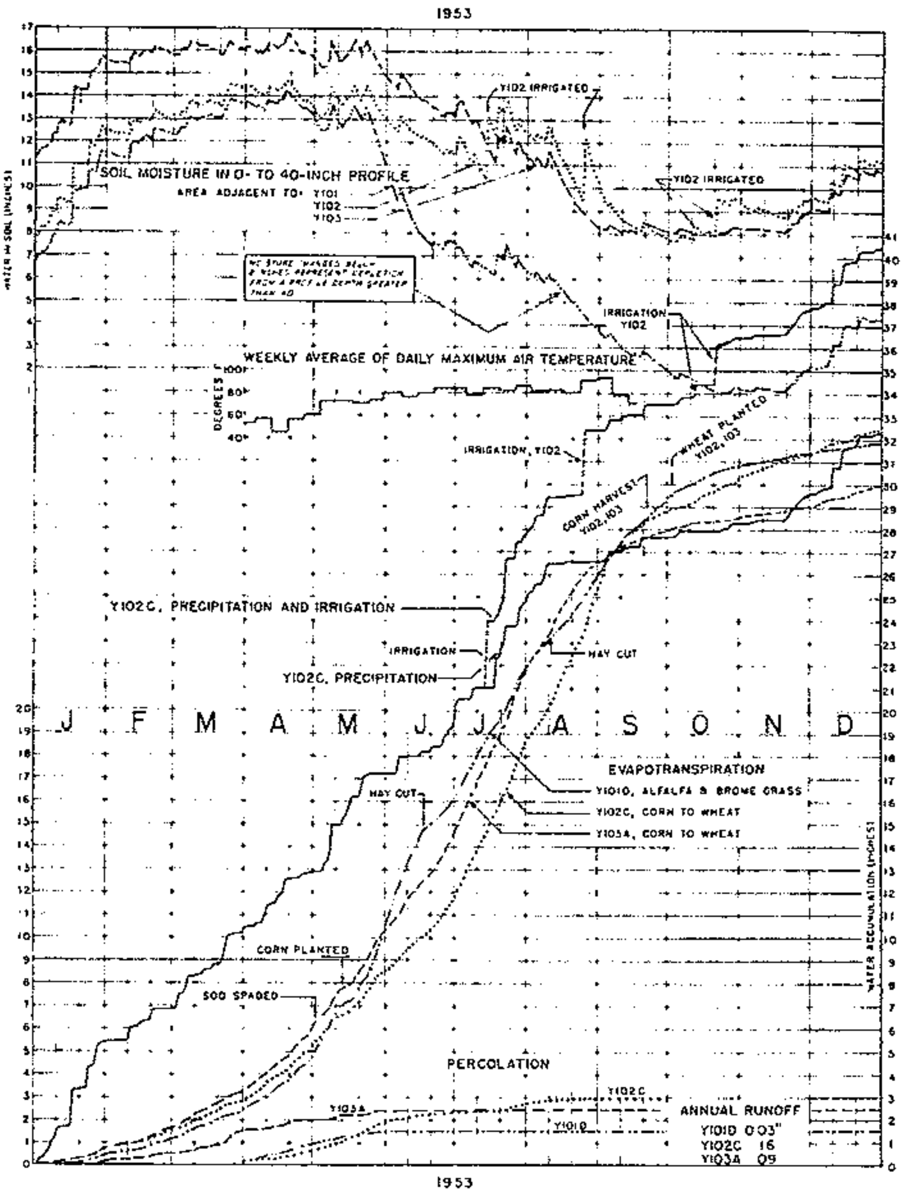

FIGURE 15. Daily soil moisture, accumulated daily precipitation, evapotranspiration (ET + CA), percolation, and weekly average air temperature, lysimeters Y101D, Y102C, and Y103A, 1953.

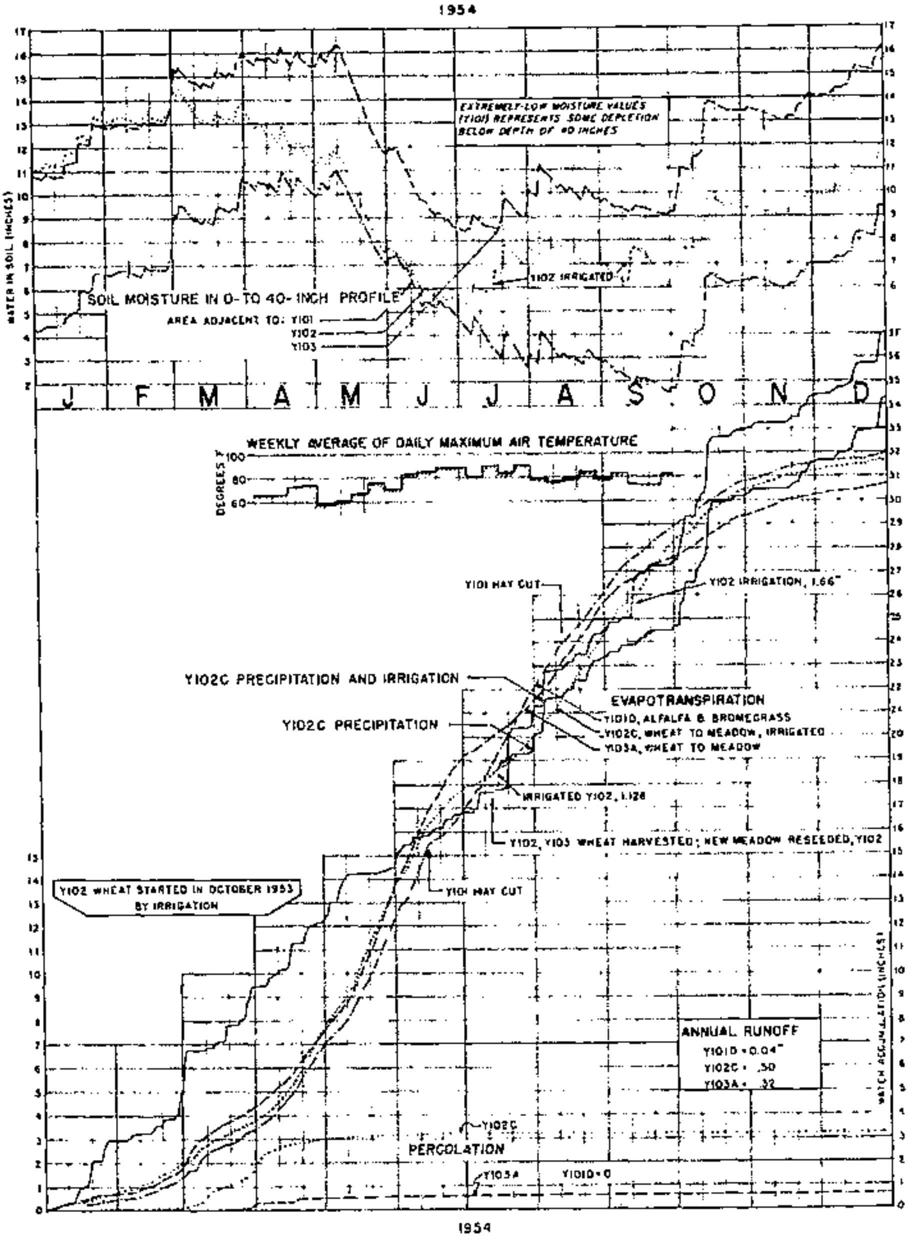

FIGURE 16. Daily soil moisture, accumulated daily precipitation, evapotranspiration (ET - CA), percolation, and weekly average air temperature, lysimeters Y101D, Y102C, and Y103A, 1954.

the separation reappeared because of the low water use on Y102C after wheat harvest. Irrigation on Y102C also helped to widen the separation of these two curves.

Daily fluctuations of soil moisture differed with depth of soil (fig. 18). The major changes of soil moisture occurred in the A horizon (0- to 7-inch depth). Both accretion and

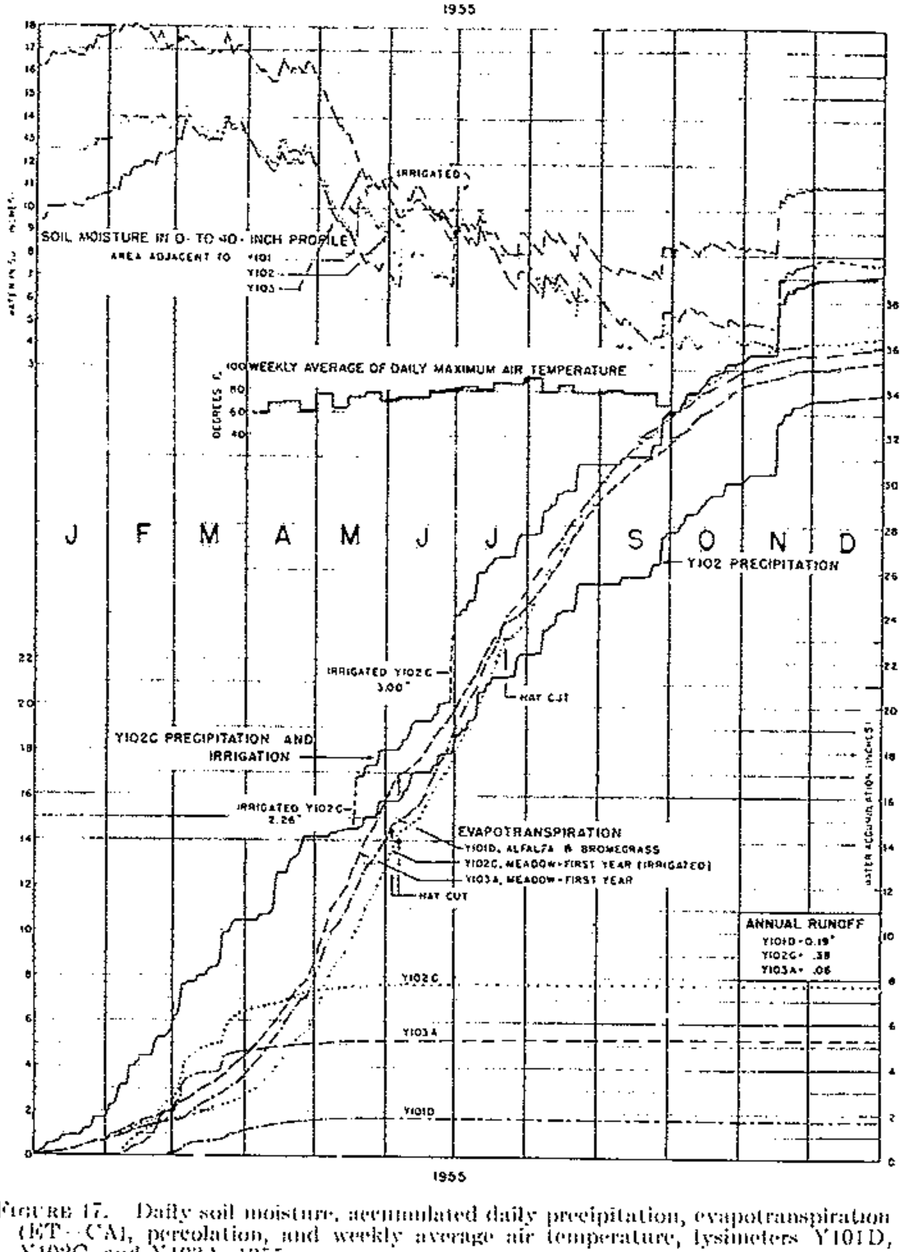

FIGURE 17. Daily soil moisture, accumulated daily precipitation, evapotranspiration (ET—CA), percolation, and weekly average air temperature, lysimeters Y101D, Y102C, and Y103A, 1955.

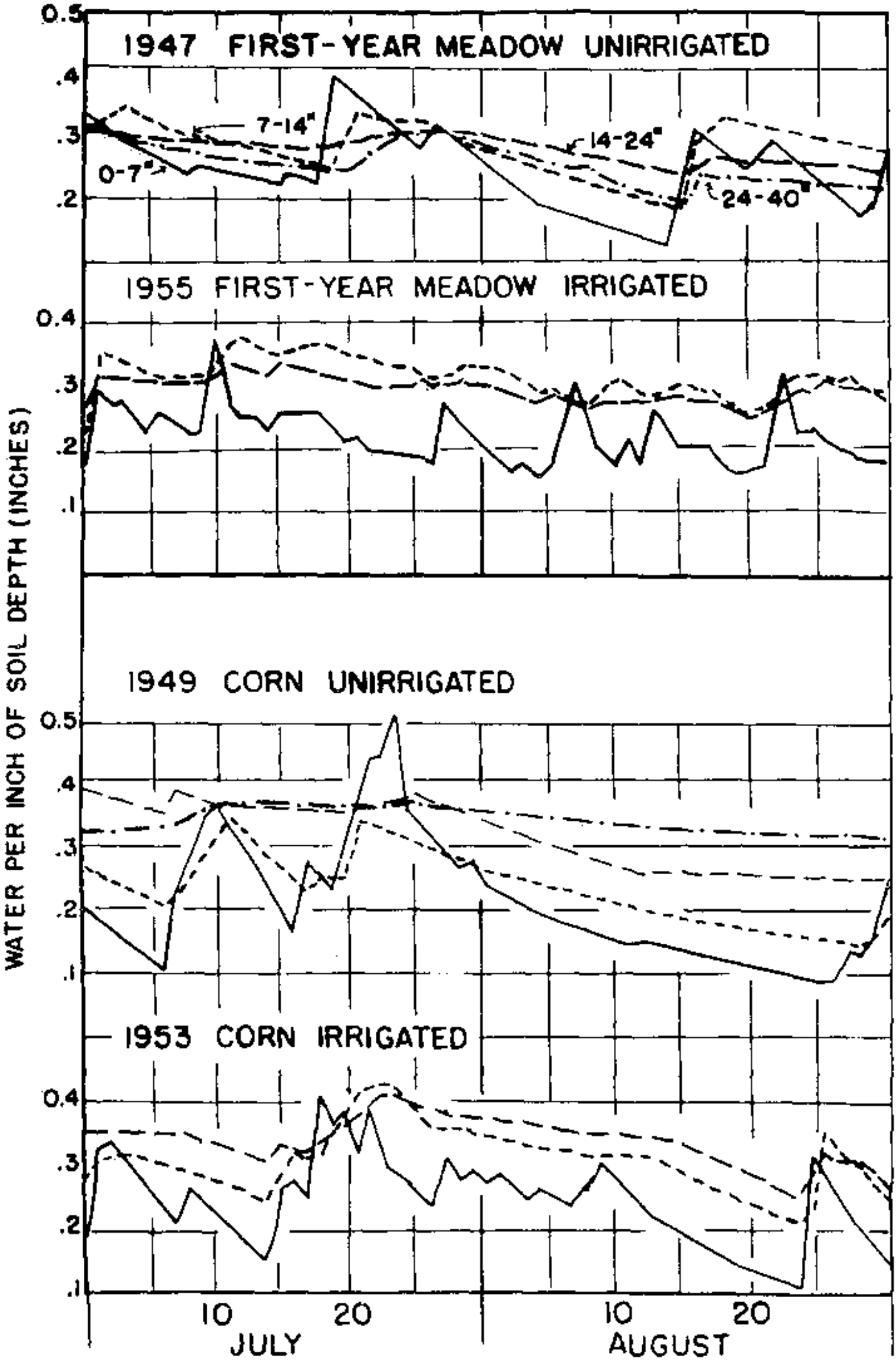

Figure 18.—Typical July and August soil-moisture fluctuations at different depths, unirrigated and irrigated meadow and corn.

depletion were more rapid in this layer, the fluctuations diminishing with increasing depth of soil. The curves of daily soil-moisture fluctuations in July and August indicate that storm rainfall and the water of irrigation are frequently stored in pore space in the top 7 inches of soil. Storage of storm rainfall below the 7-inch depth is much less frequent during these months, and then only relatively small quantities are stored. The moisture curves for the 4 sections of the profile are separated in the unirrigated years 1947 and 1949. There is no curve for the 20- to 40-inch section of the profile in 1953 and 1955. Depletion of soil moisture below the 7-inch depth on irrigated areas was much less than on unirrigated areas.

The extraction of moisture from the top 7 inches of soil on unirrigated lysimeter Y102A and on irrigated lysimeters Y102B and Y102C for the corn year 1953 and the second-year meadow 1955 can be compared for several periods during each growing season with data in table 9. As moisture content of the soil was below field capacity for all these periods, the extraction of moisture can be attributed entirely to ET. There appears to be no overall consistent difference between the depletion rates from unirrigated and irrigated lysimeters. After the irrigation of July 14, 1953, on corn lysimeters Y102B and Y102C, depletion from their 7-inch profiles was higher than from Y102A.

TABLE 9. *Comparison of average daily depletion of soil moisture from the top 7 inches of soil in a corn year (1953) and in a meadow year (1955) on unirrigated lysimeter Y102A and on irrigated lysimeters Y102B and Y102C, and ratio of depletion from the top 7 inches to depletion from the 8-foot lysimeter monolith on Y102C*

Period	Rainfall	Average daily depletion [1]: Unirrigated Y102A top 7 inches	Irrigated Y102B [2] top 7 inches	Irrigated Y102C [2]: Top 7 inches	8-foot monolith	Ratio: Top 7 inches to 8-foot monolith
1953 (corn):	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Percent*
June 12–17	0.22	0.04	0.06	0.02	0.08	25
June 17–21	.12	.12	.08	.14	.14	100
July 7–13	.47	.13	.12	.12	.21	57
July 17–27	2.67	.24	.28	.28	.44	64
July 31–Aug. 6	.76	.13	.12	.12	.19	63
Aug. 10–20	.07	.10	.10	.09	.25	36
1955 (meadow):						
May 9–18	.22	.03	.03	.04	.05	80
May 25–June 29	2.35	.07	.09	.09	.16	56
July 1–12	1.89	.18	.21	.20	.22	91
July 13–27	.68	.07	.08	.09	.19	47
July 29–Aug. 10	1.12	.11	.14	.13	.22	59
Aug. 10–22	.91	.10	.08	.08	.19	42

[1] Based on soil-moisture block readings in the 0- to 7-inch depth and on weight changes recorded on the 8-foot deep lysimeter.

[2] Irrigated as follows: 1953—July 14, 2.67 inches; Aug. 25, 2.89 inches. 1954—May 18, 2.25 inches; June 20, 3.07 inches.

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The data in table 9 show that for the periods of high rates of water consumption about 60 percent of the total moisture depletion from corn lysimeter Y102C came from the top 7 inches of the soil profile. For meadow, this figure reached a maximum of 91 percent for the period July 1 to 12, 1955.

Cumulative evapotranspiration plotted along with cumulative rainfall (figs. 6-17) emphasizes the large proportion of the moisture supply consumed through evapotranspiration.

Several items of interest and importance can be observed by a study of the curves of accumulated evapotranspiration (ET—CA). All curves start out with low slope for the first 3 months of each year. The increase in slope of these curves from April on through the growing season represents the increase in rate of consumptive use by vegetation, the steepest slope corresponding with the greatest rate of ET—CA. The decrease in slope of the curves near the end of the growing season is a result of (1) insufficient soil moisture to support the crop demand for water and (2) the crop reaching maturity and being unable to use water at high rates. In 1953, irrigation on Y102C supplied water to meet the corn needs throughout the growing season and the evapotranspiration curve continued at a steep slope into September. In contrast, on Y103A the slope of the curve decreased noticeably in late August and became very low by September 10, when there was not enough soil moisture to prevent wilting.

Rapid changes in slope of the evapotranspiration curves correspond to harvest of the hay crop, as shown in figure 13. After cutting of hay the rate of consumptive use decreased strikingly, thus causing the ET—CA curve to decrease sharply in slope. After the first cutting of hay, the ET—CA curve regained its steep slope in about 10 to 15 days. Whenever the second cutting of hay was in August, the rate of consumptive use never regained its high rate.

Cumulative percolation values vary considerably from year to year, with relatively large amounts in 1950 and only small amounts in the dry years of 1953 and 1954. Each year, most of the percolation occurred in the season of high soil moisture. Annual runoff values for all years were relatively small.

The weekly averages of daily maximum air temperature are also plotted in figures 6 to 17. These averages fairly present a picture of temperature changes during the growing season for each of the years 1944-55.

THE LYSIMETER AS A RAIN GAGE

The sampling area of the United States Weather Bureau Fergusson gage is 50 square inches (8-inch diameter), whereas the sampling area of the lysimeter is 12,540 square inches (6.22 × 14-foot rectangle). Rain falling on both is weighed. The former may be greatly affected by wind currents; the latter, to a much smaller degree. Using the lysimeter weight record as the more accurate measure of precipitation at the Coshocton station, it is possible by comparison to evaluate the accuracy of the Fergusson-gage record.

Monthly and annual values of precipitation (snow or rain) obtained by these two methods at lysimeter site Y102 during the 11-year period 1945-55 appear in table 10. The Fergusson-recorder data were obtained by pouring the captured water into a calibrated measuring tube soon after each storm. Out of a total of 132 monthly values, there were only 17 times when the monthly value for the Fergusson catch was greater than for the lysimeter; the largest plus deviation was 0.29 inch in October 1954. There were 115 times when the Fergusson-gage monthly value was less; the largest deviation was 2.51 inches in January 1951. The average deviation for the 11-year period ranged from -0.92 inch in January to -0.01 inch in July. Deviations were generally small from April through October for the entire 11-year period.

The average annual value for the Fergusson catch was 4.38 inches less than for the lysimeter for the period 1945-55. Maximum deviation in 1 year was 9.60 inches in 1951; 8.42 inches of this deviation occurred in January, February, March, and December. Rainstorms accounted for only 2.68 inches of the 9.60-inch total and snow or rain and snowstorms accounted for the remaining 6.92 inches. Comparison of individual rainstorm records and averages of groups for 1951 (fig. 19) shows no consistent deviation between the two methods of gaging rainfall.

Daily values of rainfall for both the Fergusson gage and the lysimeter for the years 1950-55 are given in tables 11-16. Data for these 6 years are representative of the entire 11-year period. Years of high and low precipitation are included in these tables. Data for days of snow and for days of less than 0.1 inch of precipitation are not included. The data are grouped by season and size of daily rain. The number of days when the Fergusson catch was greater than, less than, or equal to that of the lysimeter is shown. The total difference in rainfall catch and the average difference per day are given. In 1950 (table 11 and fig. 19), there appears to be some consistency; the Fergusson-gage data were about 10 percent less than the lysimeter data. In 1951 (table 12), the Fergusson catch is generally smaller but with less consistency. For 1953 and 1955 (fig. 19 and tables 14 and 16), the scatter of points above and below the line of equal values indicates no consistent deviation in the daily rainstorm values. It is evident that the greatest portion of the annual differences in precipitation catch is found in snowstorms or rains of less than 0.1 inch.

The Fergusson gage and other similar rain and snow gages used over the country are satisfactory for most purposes but not for a lysimeter hydrologic study such as that at Coshocton. Here the lysimeter precipitation value must be derived and used in order to arrive at a complete water-balance record.

THE LYSIMETER FOR MEASURING EVAPOTRANSPIRATION AND CONDENSATION-ABSORPTION

The automatic recording mechanism of the weighing lysimeters provided records from which were calculated the moisture transfer from vapor form in the atmosphere to liquid form on the vegetation or on the soil and, conversely, from liquid form on the soil or in or on the vegetation to vapor form in the atmosphere. In vapor form, the moisture is not weighed. In liquid form, the moisture is weighed. On days of no precipitation, weight increases during that portion of the day when the weight was continuously gaining were attributed to condensation and absorption of moisture from the atmosphere. This phenomenon is labeled CA in this report. Also, on days of no precipitation, weight decreases were attributed to evapotranspiration, labeled ET in this report. In calculating CA and ET, the amount

TABLE 10.—*Precipitation obtained by Fergusson rain gage and on ground surface of lysimeter Y102C, by months, 1945–55*

Year and gage	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1945:													
Fergusson gage	1.04	2.36	8.06	4.40	4.70	3.93	2.72	1.12	9.68	2.68	3.45	1.35	45.49
Lysimeter	1.63	2.93	9.03	4.88	5.32	4.34	2.85	1.23	9.66	2.74	3.85	2.40	50.86
1946:													
Fergusson gage	.58	3.72	2.21	1.50	5.53	6.44	5.21	2.40	.68	4.26	2.56	2.32	37.41
Lysimeter	1.09	4.63	2.61	1.87	5.98	6.72	5.33	2.40	.88	4.38	2.74	2.83	41.46
1947:													
Fergusson gage	4.84	.36	.74	3.96	6.29	5.72	2.72	3.65	3.02	.97	2.34	1.18	35.79
Lysimeter	5.35	1.15	2.33	4.28	6.43	5.65	2.84	3.76	3.13	1.04	2.67	1.49	40.12
1948:													
Fergusson gage	1.91	2.78	4.43	5.04	3.42	4.81	3.49	.92	3.33	2.69	2.83	2.02	37.67
Lysimeter	3.42	3.14	4.80	5.17	3.65	5.05	3.57	1.12	3.74	2.85	3.23	2.31	42.05
1949:													
Fergusson gage	4.79	2.61	3.42	2.68	2.86	2.91	7.56	2.57	3.44	.90	1.28	2.42	37.44
Lysimeter	5.54	2.85	3.89	2.93	3.01	3.40	6.71	2.68	3.45	1.03	1.55	2.94	39.98
1950:													
Fergusson gage	8.18	3.21	2.06	4.15	4.17	2.04	6.79	2.18	5.38	1.43	5.56	2.13	47.28
Lysimeter	9.11	3.74	3.01	4.44	4.42	2.27	6.98	2.14	5.61	1.50	6.41	3.32	52.95
1951:													
Fergusson gage	3.90	2.45	4.39	3.10	2.41	5.54	2.93	.55	3.09	1.84	4.37	3.66	38.23
Lysimeter	6.41	4.83	5.80	3.41	2.38	5.73	2.90	.65	3.02	1.88	5.04	5.78	47.83
1952:													
Fergusson gage	5.65	2.32	2.97	3.85	4.08	2.94	4.10	2.01	2.62	.77	1.63	2.22	35.16
Lysimeter	6.34	2.92	4.01	4.14	3.92	2.69	3.94	2.05	2.56	.78	1.72	2.64	37.71
1953:													
Fergusson gage	4.71	1.13	2.60	2.33	4.19	2.25	5.00	1.64	1.04	.47	.95	2.03	28.34
Lysimeter	5.44	1.44	3.44	2.61	4.28	2.36	5.22	1.79	1.10	.63	1.32	2.69	32.32
1954:													
Fergusson gage	2.22	1.80	3.39	2.98	2.21	2.14	3.38	3.33	1.23	5.77	1.00	2.36	31.81
Lysimeter	2.97	2.06	4.43	2.82	2.20	2.31	3.32	3.22	1.33	5.48	1.43	2.68	34.25
1955:													
Fergusson gage	.98	2.71	4.44	3.55	1.51	2.61	3.54	3.35	2.33	2.11	3.18	.28	30.59
Lysimeter	1.70	3.81	4.96	3.73	1.58	2.92	3.61	3.12	2.36	2.23	3.48	.35	33.85

Average, 1945–55:													
Fergusson gage	3. 53	2. 31	3. 52	3. 41	3. 76	3. 76	4. 31	2. 16	3. 26	2. 17	2. 65	2. 00	36. 84
Lysimeter	4. 45	3. 05	4. 39	3. 66	3. 92	3. 95	4. 30	2. 20	3. 35	2. 23	3. 04	2. 68	41. 22
Amount Fergusson catch differed from lysimeter catch:													
Average	. 92	−. 74	−. 87	−. 25	−. 16	−. 19	−. 01	−. 04	−. 09	−. 06	−. 39	−. 68	−4. 38
Extremes	−2. 51	−2. 38	−1. 59	−. 48	−. 62	−. 49	−. 22	−. 20	−. 41	−. 16	−. 85	−2. 12	−9. 60
	−. 51	−. 24	−. 37	+. 16	+. 16	. +25	+. 85	+. 13	+. 07	+. 29	−. 09	−. 07	−2. 44
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Months Fergusson catch was greater	0	0	0	1	3	2	4	3	3	1	0	0	0
Months Fergusson catch was less	11	11	11	10	8	9	7	7	8	10	11	11	11

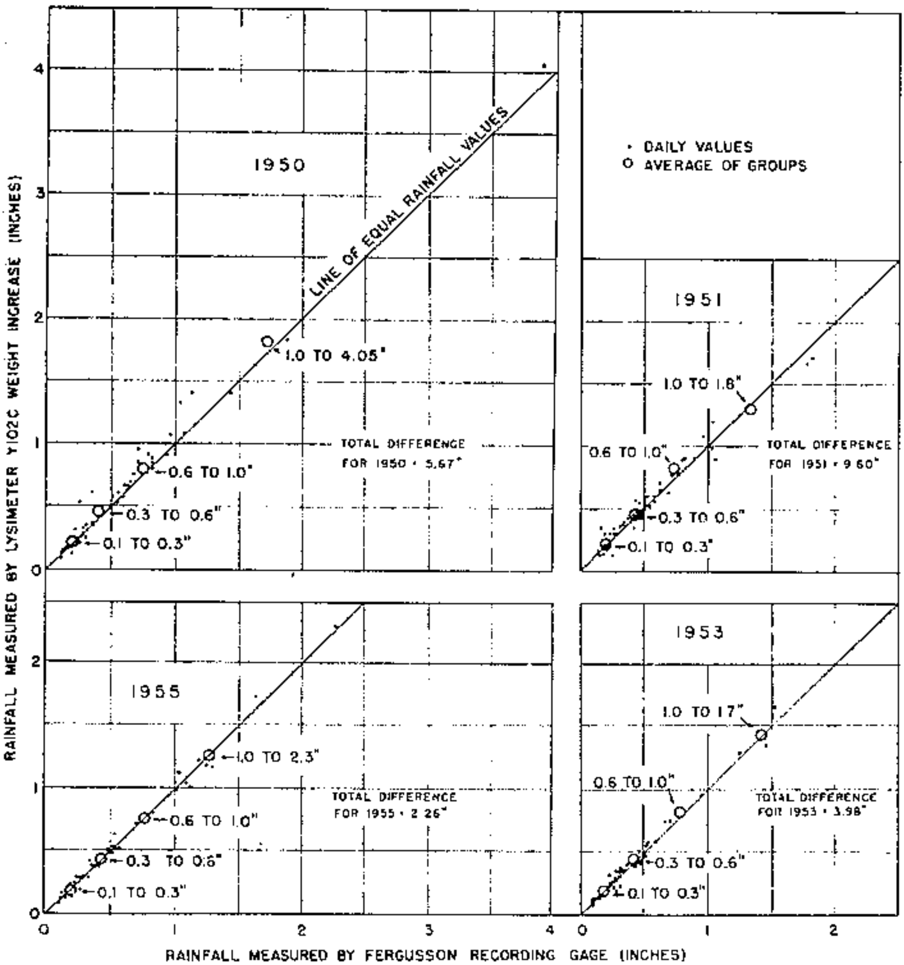

FIGURE 19.—Comparison of daily rainfall data from Fergusson recording gage and from lysimeter Y102C weight record, 1950, 1951, 1953, and 1955.

of percolation, which was measured separately, was taken into account as indicated below:

CA = Weight increase plus percolation

ET = Weight decrease minus percolation

(All figures are inches of water)

ET is a combination of (1) evaporation of moisture from the ground surface, including the surface of vegetation; and (2) transpiration, the removal of water from the soil by crops. The two phenomena operate together in nature to deplete soil moisture. The amount of soil-moisture depletion caused by evaporation and transpiration may be compensated in

TABLE 11.—*Comparison of daily rainfall catch as determined by lysimeter Y102C and by Fergusson recording gage, by size of rain, 1950*

Period	0.1- to 0.3-inch rains		0.3- to 0.6-inch rains		0.6- to 1.0-inch rains		Rains over 1.0 inch	
	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January–April	0.28	0.27	0.43	0.50	0.72	0.77	1.07	1.08
	.14	.15	.36	.62	.71	.96	------	------
	.27	.25	.56	.60	.96	1.08	------	------
	.28	.32	.37	.47	.93	1.01	------	------
	.16	.18	.37	.42	.75	.80	------	------
	.11	.07	.34	.33	.62	.62	------	------
	.21	.22	.55	.53	.72	.85	------	------
	.16	.21	------	------	.69	.76	------	------
	.22	.31	------	------	.69	.77	------	------
	.24	.53	------	------	.63	.64	------	------
	.16	.17	------	------	------	------	------	------
	.12	.12	------	------	------	------	------	------
	.13	.16	------	------	------	------	------	------
	.17	.18	------	------	------	------	------	------
	.17	.17	------	------	------	------	------	------
	.23	.23	------	------	------	------	------	------
	.26	.20	------	------	------	------	------	------
May–September	.11	.15	.40	.40	.64	.67	1.89	1.84
	.12	.12	.30	.34	.80	.92	1.63	1.64
	.16	.19	.51	.58	.83	.85	1.43	1.41
	.26	.31	.36	.39	.66	.69	3.87	4.05
	.13	.12	.37	.43	.61	.64	------	------
	.22	.22	.35	.37	.70	.70	------	------
	.18	.18	.60	.57	.93	.91	------	------
	.26	.24	.34	.38	.60	.66	------	------
	.20	.12	------	------	------	------	------	------
	.13	.16	------	------	------	------	------	------
October–December	.27	.28	.37	.42	.82	.80	1.13	1.41
	.16	.18	.40	.43	.83	.88	1.05	1.34
	.20	.21	.30	.34	------	------	------	------
	.30	.25	------	------	------	------	------	------
	.28	.26	------	------	------	------	------	------
	.16	.22	------	------	------	------	------	------
Days of record...number..	33		18		20		7	
Days of equal catch...do..	6		1		2		0	
Days Fergusson catch was greater.........do..	9		3		2		2	
Days Fergusson catch was less............do..	18		14		16		5	
Total amount Fergusson catch differed from lysimeter catch [1] inches..	−.50		−.84		−1.14		−.70	
Average difference in catch per day [1].....do..	−.015		−.047		−.057		−.100	

[1] Total difference for the year=5.67 inches.

TABLE 12.—*Comparison of daily rainfall catch as determined by lysimeter Y102C and by Fergusson recording gage, by size of rain, 1951*

Period	0.1- to 0.3-inch rains		0.3- to 0.6-inch rains		0.6- to 1.0-inch rains		Rains over 1.0 inch	
	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January–April	0.18	0.26	0.35	0.40	0.96	1.08	1.04	1.22
	.20	.13	.50	.56	.82	.91		
	.16	.35	.46	1.39	.65	.65		
	.17	.14	.35	.37	.63	.72		
	.20	.20	.47	.56	.80	.90		
	.18	.31	.50	.52				
	.20	.24	.41	.45				
	.16	.13						
	.26	.30						
	.19	.19						
	.17	.19						
	.14	.14						
	.25	.24						
	.14	.14						
May–September	.20	.18	.39	.39	.70	.64	1.78	1.68
	.23	.22	.44	.48	.63	.65	1.06	.90
	.11	.12	.30	.31	.90	.91	1.03	.99
	.29	.31	.34	.38			1.81	1.71
	.13	.16	.31	.36				
	.26	.35	.39	.40				
	.18	.21	.58	.60				
	.21	.22	.37	.38				
			.38	.46				
			.32	.32				
			.55	.52				
October–December	.20	.22	.42	.35	.61	.64		
	.28	.31	.48	.47	.78	.78		
	.18	.19	.40	.45	.73	.77		
	.25	.27	.58	.56	.73	.84		
	.10	.11	.43	.58				
	.20	.20	.37	.42				
	.28	.25	.50	.59				
			.52	.61				
Days of record...number	29		26		12		5	
Days of equal catch ...do	5		2		2		0	
Days Fergusson catch was greater...do	7		4		1		4	
Days Fergusson catch was less...do	17		20		9		1	
Total amount Fergusson catch differed from lysimeter catch [1]...inches	−.58		−1.77		−.55		+.22	
Average difference in catch per day [1]...do	−.020		−.068		−.046		+0.44	

[1] Total difference for the year=9.60 inches.

TABLE 13.—*Comparison of daily rainfall catch as determined by lysimeter Y102C and by Fergusson recording gage, by size of rain, 1952*

Period	0.1- to 0.3-inch rains		0.3- to 0.6-inch rains		0.6- to 1.0-inch rains		Rains over 1.0 inch	
	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January–April	0.26	0.26	0.35	0.43	0.63	0.66	2.71	2.64
	.17	.23	.38	.40	.76	.95	1.01	1.24
	.14	.17	.36	.44	.83	.85	1.29	1.24
	.14	.17	.30	.32	.62	.56	------	------
	.20	.23	.32	.38	------	------	------	------
	.30	.30	.34	.38	------	------	------	------
	.16	.22	.31	.28	------	------	------	------
	.29	.26	.33	.31	------	------	------	------
	------	------	.45	.49	------	------	------	------
	------	------	.38	.48	------	------	------	------
	------	------	.48	.51	------	------	------	------
May–September	.12	.14	.56	.53	.91	.80	1.47	1.26
	.27	.28	.34	.36	.64	.62	1.22	1.16
	.14	.18	.35	.31	.92	.82	1.77	1.62
	.28	.29	.52	.49	.90	.88	1.04	1.03
	.23	.25	.32	.28	.82	.78	------	------
	.24	.25	.35	.38	------	------	------	------
	.23	.21						
	.14	.19	------	------	------	------	------	------
	.14	.15	------	------	------	------	------	------
	.16	.18	------	------	------	------	------	------
	.21	.18	------	------	------	------	------	------
	.12	.10	------	------	------	------	------	------
October–December	.28	.24	.47	.47	.71	.76	------	------
	.22	.18	.55	.56	------	------	------	------
	.16	.17	.43	.39	------	------	------	------
	.11	.12	------	------	------	------	------	------
Days of record ... number	24		20		10		7	
Days of equal catch ... do	2		1		0		0	
Days Fergusson catch was greater ... do	6		7		6		6	
Days Fergusson catch was less ... do	16		12		4		1	
Total amount Fergusson catch differed from lysimeter catch[1] ... inches	−.24		−.27		+.06		+.22	
Average difference in catch per day[1] ... do	−.010		−.014		+.006		+.031	

[1] Total difference for the year=2.55 inches.

TABLE 14.—*Comparison of daily rainfall catch as determined by lysimeter Y102C and by Fergusson recording gage, by size of rain, 1953*

Period	0.1- to 0.3-inch rains		0.3- to 0.6-inch rains		0.6- to 1.0-inch rains		Rains over 1.0 inch	
	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inc[illegible]*
January-April	0.19	0.23	0.48	0.41			1.53	1.[illegible]
	.16	.17	.36	.42				
	.12	.14	.51	.48				
	.25	.27	.52	.57				
	.18	.23	.53	.58				
	.10	.14	.46	.53				
	.10	.09	.45	.50				
	.12	.16	.49	.44				
	.18	.24						
	.10	.11						
	.20	.20						
	.11	.14						
	.27	.29						
	.23	.33						
May-September	.27	.30	.31	.24	0.82	0.78	1.46	1.35
	.27	.30	.34	.37	.67	.76	1.26	1.30
	.28	.29	.32	.39	.96	.96		
	.10	.12	.51	.51	.70	.76		
	.16	.20	.44	.41				
	.12	.16	.31	.37				
	.12	.12	.47	.48				
	.28	.28	.45	.49				
	.26	.23	.44	.44				
	.23	.25	.60	.60				
	.28	.36	.40	.42				
	.21	.26	.42	.43				
	.14	.17						
October-December	.12	.14	.30	.31	.80	.87		
	.23	.26	.36	.42				
Days of record....number	29		22		5		3	
Days of equal catch....do	2		3		1		0	
Days Fergusson catch was greater....do	3		5		1		1	
Days Fergusson catch was less....do	24		14		2		2	
Total amount Fergusson catch differed from lysimeter catch [1]....inches	.71		-.34		-.18		-.06	
Average difference in catch per day [1]....do	-.024		-.015		-.036		-.020	

[1] Total difference for the year=3.98 inches.

TABLE 15.—*Comparison of daily rainfall catch as determined by lysimeter Y102C and by Fergusson recording gage, by size of rain, 1954*

Period	0.1- to 0.3-inch rains		0.3- to 0.6-inch rains		0.6- to 1.0-inch rains		Rains over 1.0 inch	
	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January–April	0.16	0.17	0.32	0.32	0.84	0.91	1.07	1.03
	.16	.18			.64	.64		
	.18	.25			.64	.69		
	.10	.09			.76	.77		
	.12	.18			.83	.81		
	.26	.24						
	.26	.28						
	.28	.35						
	.13	.18						
	.23	.19						
	.25	.28						
May–September	.29	.29	.46	.41	.76	.69	1.50	1.44
	.13	.16	.58	.54	.92	.94		
	.20	.23	.48	.44	.84	.78		
	.22	.24	.58	.65				
	.20	.21	.31	.31				
	.15	.17	.39	.38				
	.11	.12	.51	.44				
	.26	.26	.32	.33				
	.22	.21	.58	.52				
	.10	.11	.31	.33				
	.16	.15						
	15	.14						
	.24	.21						
	.14	.19						
	.24	.24						
October–December	.21	.20	.56	.53	.96	.89	2.07	1.84
	.29	.26			.77	.73		--
	.27	.29			.74	.85		--
	.27	.27			.43	.39		--
	.11	.16						--
	.10	.10						--
Days of record number	32		12		12		3	
Days of equal catch do.	5		2		1		0	
Days Fergusson catch was greater do.	9		7		6		3	
Days Fergusson catch was less do.	18		3		5		0	
Total amount Fergusson catch differed from lysimeter catch[1] inches	−.41		+.18		+.04		+.33	
Average difference in catch per day[1] inches	−.013		+.015		+.033		+.110	

[1] Total difference for the year=2.44 inches.

Table 16.—Comparison of daily rainfall catch as determined by lysimeter Y102C and by Fergusson recording gage, by size of rain, 1955

Period	0.1- to 0.3-inch rains		0.3- to 0.6-inch rains		0.6- to 1.0-inch rains		Rains over 1.0 inch	
	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C	Fergusson gage	Lysimeter Y102C
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January–April	0.12	0.16	0.38	0.38	0.77	0.74	1.01	1.00
	.27	.20	.54	.52			1.02	1.13
	.19	.24	.51	.49			1.25	1.19
	.26	.29	.41	.37				
	.18	.15	.36	.32				
	.20	.18	.42	.43				
	.10	.09	.48	.49				
	.22	.25	.51	.54				
	.15	.12						
	.22	.21						
	.12	.12						
	.11	.14						
	.24	.28						
May–September	.18	.14	.35	.38	.83	.81	1.08	1.05
	.20	.14	.53	.65	.70	.72	1.12	1.02
	.27	.30	.33	.42			1.29	1.17
	.19	.23	.48	.48			1.19	1.22
	.24	.28	.47	.44				
	.14	.18	.36	.38				
	.28	.31	.57	.52				
	.27	.24	.36	.34				
	.18	.15	.48	.52				
	.10	.12						
	.22	.22						
October–December	.25	.24	.36	.38			2.27	2.29
	.12	.15	.38	.42				
	.10	.12	.33	.20				
	.11	.15	.50	.48				
	.20	.25						
Days of record, number	29		21		3		8	
Days of equal catch, do	2		2		0		0	
Days Fergusson catch was greater, do	12		9		2		5	
Days Fergusson catch was less, do	15		10		1		3	
Total amount Fergusson catch differed from lysimeter catch[1], inches	.16		-.05		+.03		+.16	
Average difference in catch per day[1], do	-.006		-.002		+.01		+.02	

[1] Total difference for the year = 2.26 inches.

whole or in part by water added to the soil through condensation and absorption. The net soil-moisture depletion resulting from these processes (designated ET—CA) is a very convenient value in agricultural hydrology. For drainage-basin studies involving the hydrologic cycle, ET—CA values should be used instead of ET alone, as explained in a previous section.

In watershed flood control and soil-and-water-conservation programs, the volume of air space in the soil and the possibility of increasing it and using it are important. The soil pores may be needed to store all or part of the storm rainfall. Not only the volume of air space in the soil, but also the size and arrangement of pores and other factors govern the capacity of the soil to transmit rainfall; in other words, its permeability rate. When the water in pores is replaced by air, oxygen is made available for plant use. When air replaces water in too many pores, however, crop failure may result because of insufficient moisture.

The magnitude of CA and ET and their diurnal occurrence may be observed in figures 20, 21, and 22. These are typical of corn and meadow fields and represent both dry and wet conditions in a well-drained soil (Y102C) and fairly dry conditions in a slowly permeable soil (Y103A). Whenever the line in the graph is above zero, there is weight gain (CA) for these hours. These periods, indicated on the graph in solid black, are commonly found in the late afternoon or early night. The amount of CA for each day is shown as a *plus*, for example, +0.054 inch for lysimeter Y103A on August 28, 1953 (fig. 21). Whenever the line is below zero there is weight loss (ET) for these hours. These periods extend most generally from early morning to late afternoon. The amount of ET for each day is shown as a *minus*, for example, −0.152 inch for lysimeter Y103A on August 28, 1953 (fig. 21). Consumptive use (ET—CA) for this day is $+0.054-0.152=-0.098$ inch.

Whenever the word evapotranspiration is used to express ET—CA, it is so noted, as in figures 6 through 17. The graphs of accumulated evapotranspiration are actually

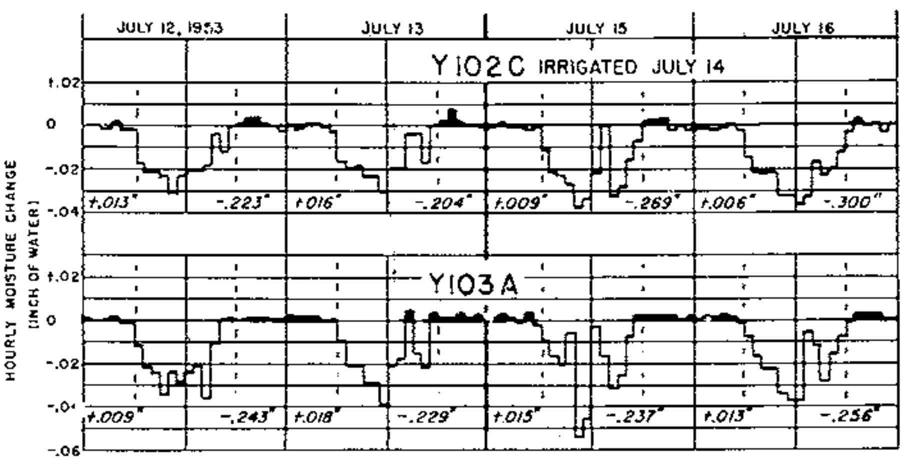

FIGURE 20.—Hourly moisture changes in irrigated and unirrigated corn lysimeters Y102C and Y103A before and after irrigation July 14, 1953.

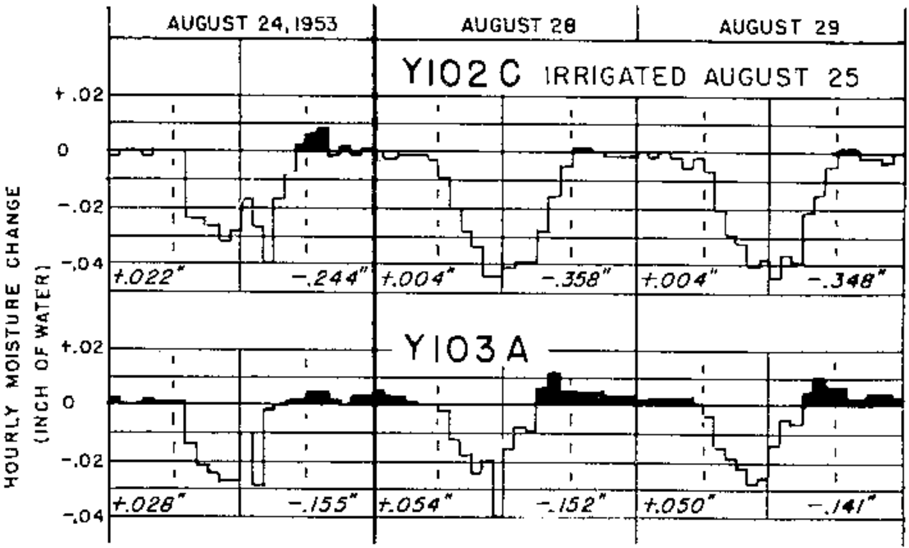

FIGURE 21. Hourly moisture changes in irrigated and unirrigated corn lysimeters Y102C and Y103A before and after irrigation August 25, 1953.

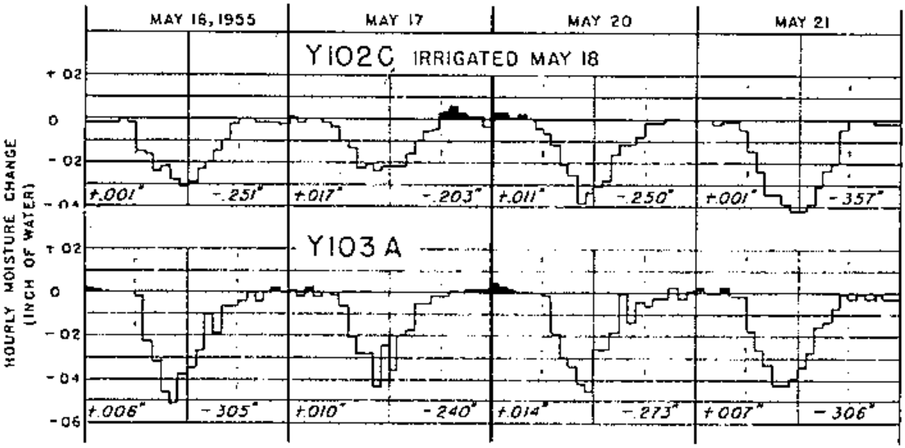

FIGURE 22. Hourly moisture changes in irrigated and unirrigated meadow lysimeters Y102C and Y103A before and after irrigation May 18, 1955.

ET−CA. The slope of these lines represents the net daily depletion of soil moisture for 24 hours ending at midnight.

In irrigation practice, ET−CA values should be used. They are commonly referred to as "consumptive use" or "crop use of water." Actually, vegetation does not always use all this water, but the ET−CA values represent the rate of soil-moisture depletion for the crop grown. The importance of this treatment of the data will be more apparent after the section on irrigation (p. 108) is studied.

Condensation-Absorption (CA), or Dew

The average daily CA on all three weighing lysimeters is given by months and years for the period 1944-55 in table 17. The greatest average daily CA for any single month, except months affected by drifting snow, was 0.05 inch on lysimeter Y103A in October 1953. Months, except those of snow, in which the average daily CA was more than 0.02 inch were April, September, and October. Averages for the growing season (May-August) are all low.

It is likely that CA values in this report for April to October are conservative. The weight record can measure only net changes. A crop a foot or more in height could be transpiring water at the same time CA is occurring at the ground surface. Observations have shown that the temperature of the air usually cools sooner at the ground surface than a foot or so above the ground. CA values were always less for a tall crop than for no crop. For example, on May 11, 1949, CA for alfalfa-bromegrass was + 0.004 inch and for bare plowed land, + 0.059 inch. CA values (table 17) for lysimeters Y102C and Y103A in corn in 1945, 1949, and 1953 were generally greater in May than in June, July, and August. In May the ground was mostly bare, and the plus weight changes represent true CA values as there was practically no transpiration. Later the surface was covered by a crop that grew continuously taller, and the plus weight changes represented CA minus transpiration, or a net conservative value of CA.

Cutting and removal of hay resulted in an apparent increase in CA of 0.01 inch per day. CA values before and after cutting hay along with CA values for uncut hay provided a means of arriving at the magnitude of this increase in CA. The increase in CA could not be explained from climatological factors. As it was likely that ET was essentially stopped by removal of hay, CA was possibly a truer value after hay cutting than before. It is likely, therefore, that the true CA for most of the growing season was greater than could be measured by the weighing lysimeters.

Temperature changes within the soil may cause vapor in the soil pores to condense in the cooling phase of the cycle and to evaporate in the warming phase. This would result in lysimeter weight changes that should not be associated with actual increases or decreases in soil moisture. A study was made to determine the magnitude of such weight changes. Computations based on recorded soil temperature, vapor pressure, and volume of air in soil pores indicate that the amount of moisture condensed by cooling of the air in soil pores plus the moisture condensed from air drawn into the soil during the cooling period was extremely small. The daily total was less than 0.01 pound (about 0.00002 inch of water) for the lysimeter area. This factor was therefore too small to be considered, and the CA values were then assumed to be supplied entirely from atmospheric moisture.

Farmers have long recognized the value of dew (CA) in helping to supply crop moisture. Dew is apparently greater in valley fields than on hills. However, on the Coshocton lysimeters, several hundred feet above the valley floor, dew was sufficient at times to carry a crop over drought periods. One such period occurred in August 1951. With only 0.55 inch of rain that month, crops did not wilt. Dew (CA) on lysimeter Y103A amounted to 1.39 inches (table 18) with as much as 0.08 inch in a single day. The importance of *dew* in conserving soil moisture is substantiated by observations which showed that while dew was being evaporated no moisture was taken from the soil. ET values were essentially no

TABLE 17.—*Average daily condensation and absorption (CA) on lysimeters Y101D, Y102C, and Y103A, by months, 1944–55, expressed in inches of water*

Year and lysimeter [1]	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1944:													
Y101D	0.016	0.030	0.031	0.015	0.007	0.008	0.007	0.009	0.015	0.021	0.014	[2] 0.060	0.019
Y102C	.035	.023	.013	.011	.004	.004	.006	.006	.014	.025	.027	[2] .046	.018
Y103A	.024	.030	.020	.016	.005	.006	.002	.002	.007	.015	.013	[2] .050	.016
1945:													
Y101D	[2] .138	[2] .120	.028	.017	.015	.012	.010	.018	.015	.020	.029	.036	.039
Y102C	[2] .072	[2] .065	.026	.018	.021	.019	.007	.015	.015	.029	.033	.036	.030
Y103A	[2] .068	[2] .055	.018	.009	.009	.014	.008	.012	.014	.025	.032	.026	.064
1946:													
Y101D	[2] .057	[2] .052	[2] .030	.025	.017	.011	.011	.022	.030	.025	.028	[2] .043	.029
Y102C	[2] .051	[2] .041	.034	.023	.012	.006	.012	.017	.026	.029	.037	.041	.027
Y103A	[2] .044	[2] .034	.026	.013	.011	.010	.012	.017	.028	.028	.025	.026	.023
1947:													
Y101D	[2] .048	[2] .086	[2] .053	.029	.027	.017	.021	.021	.023	.028	.024	.026	.034
Y102C	[2] .048	[2] .063	.038	.031	.024	.015	.015	.024	.017	.026	.034	.039	.031
Y103A	[2] .034	[2] .049	.035	.027	.021	.015	.015	.020	.015	.025	.025	.032	.026
1948:													
Y101D	[2] .054	[2] .050	.043	.019	.008	.007	.012	.018	.013	.024	.026	[2] .040	.026
Y102C	[2] .051	[2] .072	.043	.029	.012	.009	.012	.027	.021	.027	.034	[2] .048	.032
Y103A	[2] .041	[2] .050	.041	.018	.011	.010	.014	.016	.015	.020	.028	[2] .034	.025
1949:													
Y101D	[2] .035	[2] .048	.045	.030	.011	.020	.012	.023	.025	.026	.030	.050	.030
Y102C	.038	[2] .042	.043	.028	.038	.026	.011	.022	.030	.038	.032	.039	.032
Y103A	[2] .034	[2] .041	.045	.021	.027	.023	.009	.023	.038	.041	.032	.055	.032
1950:													
Y101D	.043	[2] .057	[2] .052	.036	.022	.029	.008	.014	.018	.022	[2] .028	[2] .035	.030
Y102C	.042	[2] .061	[2] .048	.041	.018	.015	.028	.029	.024	.025	[2] .044	[2] .050	.035
Y103A	.045	[2] .066	[2] .060	.043	.016	.020	.032	.031	.022	.026	[2] .025	[2] .037	.035
1951:													
Y101D	[2] .035	[2] .060	[2] .049	.040	.017	.022	.013	.012	.012	.025	[2] .037	[2] .082	.034
Y102C	[2] .038	[2] .116	[2] .048	.046	.021	.022	.015	.038	.021	.023	[2] .035	[2] .060	.040
Y103A	[2] .037	[2] .152	[2] .055	.042	.021	.022	.018	.045	.025	.026	[2] .028	[2] .086	.046

1952:													
Y101D	[2].051	[2].051	[2].052	.032	.020	.016	.004	.018	.017	.021	[2].036	[2].032	.029
Y102C	[2].051	[2].048	[2].053	.034	.015	.017	.014	.026	.024	.034	[2].037	[2].038	.033
Y103A	[2].048	[2].047	[2].049	.025	.016	.012	.011	.017	.021	.033	[2].041	[2].035	.030
1953:													
Y101D	[2].037	[2].050	[2].041	.033	.020	.016	.011	.018	.022	.021	[2].045	[2].044	.030
Y102C	[2].035	[2].043	[2].037	.033	.035	.029	[3].012	[3].015	.025	[3].039	[2].042	[2].047	.032
Y103A	[2].031	[2].047	[2].035	.029	.024	.025	.012	.024	.041	.050	[2].038	[2].033	.032
1954:													
Y101D	[2].046	[2].048	[2].066	.035	.025	.024	.022	.025	.034	.033	[2].043	[2].048	.037
Y102C	[2].046	[2].047	[2].046	.037	.009	.016	[4].029	.024	[4].024	.030	[2].040	[2].047	.034
Y103A	[2].033	[2].037	[2].041	.031	.014	.014	.033	.022	.040	.026	[2].040	[2].039	.031
1955:													
Y101D	[2].051	[2].044	[2].062	.033	.018	.025	.019	.024	.031	.034	[2].041	[2].056	.036
Y102C	[2].041	[2].055	[2].063	.032	.010	[5].023	.019	.013	.027	.028	[2].048	[2].064	.035
Y103A	[2].034	[2].061	[2].052	.029	.012	.027	.026	.021	.037	.027	[2].034	[2].044	.034
Average:													
Y101D	[2].051	[2].058	[2].046	.029	.017	.018	.013	.019	.021	.025	[2].032	[2].046	.031
Y102C	[2].046	[2].056	[2].041	.030	.018	.017	.015	.022	.023	.029	[2].037	[2].046	.032
Y103A	[2].040	[2].056	[2].040	.025	.017	.016	.016	.021	.026	.029	[2].039	[2].041	.029

[1] For cropping history, see pp. 157–166.
[2] Some snowfall during the month; values possibly too high due to drifting of snow.
[3] Irrigated July 14, Aug. 25, and Oct. 12 and 21, 1953.
[4] Irrigated July 16 and Sept. 13, 1954.
[5] Irrigated June 29, 1955.

TABLE 18.—*Daily values of dew (CA) on lysimeter Y103A, August 1951*

Date	Dew	Date	Dew	Date	Dew
	Inches		*Inches*		*Inches*
1	0.02	12	0.06	23	0.06
2	.03	13	.07	24	.06
3	.01	14	.06	25	.06
4	.02	15	.05	26	.05
5	.03	16	.05	27	.03
6	.01	17	.08	28	.04
7	.01	18	.05	29	.05
8	.04	19	.06	30	.06
9	.05	20	.05	31	.02
10	.04	21	.05		
11	.06	22	.06	Total	1.39

greater following a heavy dew than following little or no dew. This is explained in a later section of this bulletin.

The effect of the moisture content of the surface soil on CA is shown by the changes in CA before and after irrigation (figs. 20, 21, and 22). The change is more striking on cornland (figs. 20 and 21) than on grassland (fig. 22). On August 24, 1953, before irrigation on August 25, CA on Y102C was 0.022 inch (fig. 21). On August 28 and 29, with a wet soil surface, CA was 0.004 inch per day. Data for Y103A, unirrigated, show that climatological conditions on the uniformly dry soil surface of Y103A were actually more favorable for CA on August 28 and 29, than on August 24. The wet soil of Y102C was not conducive to high values of CA.

Data for Y102C and Y103A for August, September, and October 1953 (table 17) show the effect of irrigation on CA for cornland and new wheat seeding. On the moist surface of lysimeter Y102C, average daily CA was 0.015, 0.027, and 0.038 inch per day and on the dry soil of Y103A it was 0.024, 0.041, and 0.050 inch per day, respectively, for these months.

Evapotranspiration (ET)

The average daily ET from all three weighing lysimeters is given by months and years for the period 1944–55 in table 19. As expected, ET values were highest in the growing season (May, June, and July). ET values for August and September were lower, largely because of the deficiency of soil moisture. ET values cannot be high if moisture is insufficient to meet the plant needs. This is illustrated by comparing ET values for the 1953 growing season for irrigated lysimeter Y102C with those for unirrigated lysimeter Y103A. Both were in corn. The average daily ET values in May, June, and July were higher for Y103A than for Y102C. Neither soil experienced much of a moisture deficit in these months. The ET value for Y102C, which was well supplied with moisture, remained high in August (0.233 inch per day), whereas the ET value for Y103A decreased to 0.174 inch per day because of a large moisture deficit.

Noticeable differences in ET can be observed for different crops, especially in May and June. At this season differences in the development of the vegetative canopy are very noticeable. ET values for

TABLE 19.—*Average daily evapotranspiration (ET) from lysimeters Y101D, Y102C, and Y103A, by months, 1944–55, expressed in inches of water*

Year and lysimeter [1]	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1944:													
Y101D	0.025	0.053	0.087	0.076	0.120	0.147	0.152	0.123	0.080	0.065	0.034	[2]0.059	0.085
Y102C	.049	.044	.065	.076	.146	.151	.137	.141	.105	.073	.056	[2].084	.094
Y103A	.037	.065	.104	.102	.128	.178	.151	.138	.096	.055	.034	[2].095	.099
1945:													
Y101D	[2].119	[2].152	.100	.098	.119	.160	.187	.121	.095	.100	.060	.053	.114
Y102C	[2].060	[2].094	.090	.116	.156	.132	.153	.135	.113	.104	.077	.060	.108
Y103A	[2].087	[2].084	.090	.124	.169	.151	.193	.148	.090	.104	.074	.062	.115
1946:													
Y101D	[2].077	[2].087	.115	.146	.145	.224	.200	.152	.104	.081	.063	.062	.121
Y102C	[2].079	[2].080	.124	.170	.168	.188	.180	.168	.107	.074	.073	.066	.123
Y103A	[2].072	[2].084	.118	.151	.172	.209	.218	.181	.114	.082	.055	.052	.126
1947:													
Y101D	.067	[2].100	.097	.122	.132	.199	.186	.138	.165	.092	.032	.029	.113
Y102C	.065	[2].090	.089	.104	.150	.221	.188	.154	.181	.109	.059	.054	.122
Y103A	.067	[2].078	.095	.107	.154	.230	.181	.151	.171	.099	.050	.044	.119
1948:													
Y101D	[2].056	[2].083	.111	.155	.182	.143	.190	.152	.101	.085	.071	.052	.115
Y102C	[2].063	[2].088	.097	.145	.228	.234	.197	.127	.122	.089	.075	.062	.127
Y103A	[2].051	[2].080	.104	.152	.222	.252	.197	.118	.109	.076	.057	.047	.122
1949:													
Y101D	[2].052	.071	.103	.206	.220	.204	.222	.172	.142	.112	.061	.055	.135
Y102C	.057	.075	.094	.134	.131	.173	.243	.179	.104	.091	.076	.063	.118
Y103A	.059	.079	.106	.129	.149	.197	.284	.188	.108	.086	.070	.076	.128
1950:													
Y101D	.063	[2].081	[2].104	.115	.196	.190	.236	.202	.148	.111	[2].054	.069	.131
Y102C	.073	[2].080	[2].100	.114	.198	.186	.129	.156	.142	.115	[2].086	.087	.122
Y103A	.083	[2].098	[2].124	.128	.215	.215	.153	.187	.148	.109	[2].074	.086	.135
1951:													
Y101D	[2].091	[2].112	[2].096	.122	.217	.168	.262	.120	.120	.112	[2].064	[2].136	.135
Y102C	[2].085	[2].153	[2].095	.107	.204	.190	.238	.106	.125	.098	[2].064	[2].104	.131
Y103A	[2].080	[2].218	[2].118	.116	.206	.196	.235	.118	.125	.096	[2].054	[2].136	.142

See footnotes at end of table.

TABLE 19.—*Average daily evapotranspiration (ET) from lysimeters Y101D, Y102C, and Y103A, by months, 1944–55, expressed in inches of water*—Continued

Year and lysimeter [1]	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1952:													
Y101D	[2] .075	[2] .084	[2] .102	.155	.227	.186	.242	.170	.125	.064	[2] .057	[2] .042	.127
Y102C	[2] .083	[2] .077	[2] .093	.127	.192	.206	.217	.148	.125	.074	[2] .062	[2] .048	.121
Y103A	[2] .090	[2] .093	[2] .109	.142	.212	.185	.216	.142	.122	.070	[2] .065	[2] .051	.125
1953:													
Y101D	[2] .052	[2] .075	[2] .082	.110	.203	.203	.198	.149	.140	.067	[2] .063	[2] .062	.117
Y102C	[2] .057	[2] .074	[2] .081	.111	.141	.138	[3] .231	[3] .233	.140	[3] .084	[2] .080	[2] .086	.121
Y103A	[2] .057	[2] .078	[2] .088	.119	.164	.165	.248	.174	.087	.071	[2] .052	[2] .066	.114
1954:													
Y101D	[2] .061	[2] .080	[2] .132	.155	.198	.173	.189	.155	.126	.093	[2] .071	[2] .062	.125
Y102C	[2] .081	[2] .086	[2] .107	.169	.201	.152	[4] .101	.165	[4] .152	.100	[2] .067	[2] .061	.120
Y103A	[2] .055	[2] .072	[2] .129	.140	.212	.191	.110	.158	.102	.071	[2] .071	[2] .053	.115
1955:													
Y101D	[2] .073	[2] .075	[2] .128	.174	.219	.185	.221	.173	.136	.100	[2] .067	[2] .068	.135
Y102C	[2] .067	[2] .084	[2] .098	.149	.222	[5] .187	.218	.199	.128	.112	[2] .074	[2] .074	.134
Y103A	[2] .054	[2] .112	[2] .130	.170	.241	.162	.175	.172	.123	.109	[2] .062	[2] .055	.130
Average:													
Y101D	[2] .068	[2] .088	[2] .105	.136	.182	.182	.207	.152	.124	.090	[2] .058	[2] .063	.121
Y102C	[2] .069	[2] .086	[2] .094	.127	.178	.180	.186	.159	.129	.094	[2] .071	[2] .071	.120
Y103A	[2] .066	[2] .095	[2] .110	.131	.187	.194	.197	.156	.116	.087	[2] .060	[2] .069	.122

[1] For cropping history, see pp. 157–166.
[2] Exaggerated values due to drifting of snow.
[3] Irrigated July 14, Aug. 25, and Oct. 12 and 21, 1953.
[4] Irrigated July 16 and Sept. 13, 1954.
[5] Irrigated June 29, 1955.

May and June for the corn years 1949 and 1953 averaged 0.146 and 0.169 inch per day for lysimeters Y102C and Y103A, whereas for alfalfa–bromegrass the average was 0.208 inch. A difference of 0.062 inch per day amounts to over 3 inches for the 2-month period. These differences disappeared when all three lysimeters were in about the same crop (second-year meadow in 1950 and 1954 on Y102C and Y103A and alfalfa–bromegrass on Y101D).

ET values alone show the magnitude of moisture extraction from the soil and evaporation from vegetation during a part of the day from about 6 a. m. to 4 or 6 p. m. This extraction is partly compensated for by CA. The difference (ET—CA) represents the net loss of moisture for a 24-hour day, and it is the figure most commonly used in agricultural-hydrology problems. Such data are presented later in this report under such headings as "Water Use by Crops—ET—CA" and "Irrigation."

Hourly lysimeter weight records during periods in which there was no rainfall and little or no percolation show the periods of the day during which there were gains and losses in moisture. These hourly changes in soil moisture from weighing lysimeters Y102C and Y103A (figs. 20, 21, and 22) show the magnitude of the evening–night weight gains and daytime weight losses and the effect of irrigation or evapotranspiration (ET) and condensation-absorption (CA).

CA and ET for lysimeters Y102C and Y103A on July 12 and 13, 1953 (fig. 20) represent unirrigated conditions. Irrigation on Y102C on July 14 amounted to 2.93 inches. Leaves of the corn plants shielded only part of the soil surface on these dates. ET and CA values for July 15 and 16 represent conditions of ample moisture for Y102C and deficient moisture for Y103A. Evapotranspiration, as well as condensation–absorption, was affected by soil-moisture supplies during this July period. Average ET for Y102C for July 12 and 13, prior to irrigation, was 0.214 inch per day, or 91 percent of that for Y103A. Both had received the same rainfall for months earlier. Average ET for Y102C for July 15 and 16, after irrigation, was 115 percent of that for Y103A.

Rains of 1.30 inches on July 18, 0.49 inch on July 20, and 0.96 inch on July 22 replenished moisture supplies on Y103A, and ET for Y103A again became greater than for Y102C, the natural relationship. The last rain in August occurred on the 9th, except for 0.07 inch on the 17th. By August 16, the effect of the late July and early August rains had disappeared, and the influence of the July 14 irrigation reappeared, that is, ET for Y102C again became greater than for Y103A.

On August 24, CA was slightly less on Y102C than on Y103A (fig. 19). Both soil surfaces were dry. On the same day (August 24) ET for Y102C was 157 percent of ET for Y103A. Failure of the print-weigh mechanism prior to August 24 and on August 26 and 27 prevented the development of hourly moisture-change data for consecutive 2-day periods before and after irrigation. On August 28 and 29, CA on Y102C, with a wet soil surface, was extremely low whereas on dry soil lysimeter Y103A it was extremely high. Irrigation of 2.90 inches of water on August 25 moistened the soil to a depth of 24 inches. It also provided moisture needed by the crop and possibly increased evaporation. The combined ET for Y102C rose to an average of about 240 percent of that for Y103A.

One measure of the value of irrigation in July and August 1953 is crop yields—168 bushels per acre on the 2 irrigated lysimeters Y102B and Y102C and 144 bushels per acre on the 2 unirrigated lysimeters Y103A and Y103B. In 1949, when neither Y102 nor Y103 was irrigated, yields were practically the same, averaging 150 and 151 bushels per acre, respectively.

The only irrigation in the growing season other than in the 1953 corn year was on May 18, 1955, on a first-year meadow crop of red clover, alfalfa, and timothy. Available moisture in the 24-inch soil depth had depleted to the one-half level, and 2.26 inches of water was applied. Irrigation influenced ET noticeably (fig. 20). ET for Y102C on May 16 and 17, before irrigation, averaged 83 percent of that for Y103A. On May 20 and 21, after irrigation, ET for Y102C averaged 105 percent of that for unirrigated Y103A. There is considerable variation in this relationship for the individual days—May 20 and 21. On both days, however, there was an increase in ET for Y102C after irrigation. Records for May 19 could not be used in this comparison as some of the hourly values on that day were not available.

Water use by crops (ET—CA)

The amount of water required for crop growth has been the subject of much experimentation, especially in the arid and semiarid sections of the country where irrigation of almost all cropland is necessary for production. Within recent years, however, irrigation in the humid Eastern States has been found to be profitable in many cases. The scarcity of water supplies, the cost of transporting water to the crops, and the loss of plant nutrients through leaching in almost every State have created a demand for sound technical information on the use of water by crops to help develop plans to conserve this vital natural resource.

Water-use-by-crop data are also needed in estimating the rate of removal of water from soil pores and in evaluating soil-moisture conditions antecedent to critical storm periods. Such evaluations provide an important factor needed in estimating infiltration rates and calculating storm-runoff rates and amounts.

Weight records from lysimeters Y102C and Y103A for the period 1941–55 provide data on the amount of water used by different crops in a 4-year crop rotation in their respective periods of growth (table 20). These data are for 4 corn years, 4 wheat years, 4 first-year meadow years, and 3 second-year meadow years. They show for each year and for each crop the amount of water taken from the soil in the crop period, i. e., ET—CA, or consumptive use. No effort was made to separate evaporation (E) and transpiration (T), as these two processes often function together to deplete soil moisture.

All data in table 20, except for lysimeter Y102C in 1953 and 1955, are for natural moisture conditions where periods of soil-moisture deficiencies normally occurred during some parts of July, August, and September. If there had been adequate moisture for maximum crop production during the entire growing season of each year, it is likely that greater amounts of water would have been used. Crops on lysimeter Y102C were irrigated in 1953 and 1955 and the data for these years (table 20) are for optimum moisture. Total amount of water used, crop yield, and efficiency of water use all show the effect of irrigation. (See p. 108 for a detailed description of irrigation practices and results of the studies.)

The amount of water transpired and evaporated in the May–September period in the production of corn ranged from 17.4 to 24.6 inches. Under conditions of natural moisture, greater amounts of water were used on lysimeter Y103A, where the soil is heavier and holds more water, than on the light-textured soil of Y102C. In 1953, however, water use on irrigated lysimeter Y102C exceeded that on Y103A by 1.6 inches.

Yield of corn ranged from 34 to 144 bushels per acre without irrigation. The low yield resulted from insufficient moisture and wilting in late August. With irrigation in 1953, a yield of 196 bushels per acre was produced on Y102C. This was a higher yield than on unirrigated lysimeter Y103A, a reversal of the normal relationship of these two lysimeters.

The efficiency of water use is evaluated by dividing the weight of water used (table 20, col. 5) by the dry weight of crop produced (table 20, col. 7). The result (table 20, col. 8) shows that efficiency of use on cornland without irrigation ranged from 319 to 586 pounds of water to produce a pound of crop.

The lowest value (319 pounds) corresponds to the highest yield and is the most efficient. The highest value (586 pounds) corresponds to the lowest yield and is least efficient.

The most efficient use of water—only 273 pounds of water to produce a pound of corn crop—was with irrigation on Y102C in 1953. The amount of water applied and the time of irrigation was determined by field measurements of available soil moisture and, as a result, there was neither underirrigation nor overirrigation.

Average values for lysimeters Y102C and Y103A show the same yield of corn and about 20 to 22 inches of water used with a water-efficiency value averaging nearly 400 pounds of water per pound of crop.

The total amount of water used for wheat production, ranging from 12.0 to 14.7 inches, was much less than for corn. The efficiency of water use (table 20, col. 8) was generally less for wheat than for corn. The amount of water used to produce a pound of wheat ranged from 456 to 762 pounds and averaged about 600. Crop yield, without irrigation, ranged from 32 to 48 bushels per acre and averaged less than 40.

Lysimeter Y102C was irrigated in October 1953 to start the 1954 wheat crop. Apparently this resulted in a slight increase in yield without affecting the amount of water used in the April–June period (14.0 inches for irrigated Y102C and 14.7 inches for unirrigated Y103A). Efficiency of water use was 525 pounds on the irrigated lysimeter and 608 pounds on the unirrigated lysimeter. Water supply is seldom a limiting factor in the production of wheat in this region. Excessive amounts of water on poorly drained soils may, however, result in decreased yields and less efficiency in water use.

On meadowland, yields and efficiency of water use were noticeably affected by available moisture. Water-use values for first-year meadow without irrigation ranged from 19.4 to 24.6 inches for the April–August period and averaged about 22 inches for the 4 years of record (table 20). Unirrigated crop yields ranged from 1.67 to 4.43 tons per acre. Water-use efficiency values ranged from 629 to 1,377 pounds of water per pound of hay crop.

The water-use period of April through August was selected to represent the meadow growing season. However, some persons may want values for the period beginning April 1 and ending with the date of

TABLE 20.—*Water used by crops—evapotranspiration (ET—CA)—during season of growth, 1941–55*

Crop and year	Lysimeter	Water used per acre			Crop yield per acre [1]	Dry weight of crop per acre, including straw or stover	Weight of water used to produce 1 pound of crop
		Period	Amount				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Inches	*Million pounds*		*Pounds*	*Pounds*
Corn:							
1941	Y102C	May–Sept	17.4	3.94	80 bushels	10,000	394
1945	Y102C	do	18.9	4.28	34 bushels	7,300	586
1945	Y103A	do	20.7	4.69	61 bushels	10,500	447
1949	Y102C	do	21.5	4.87	144 bushels	14,600	334
1949	Y103A	do	24.6	5.57	139 bushels	14,100	395
1953	Y102C	do	[2] 23.5	5.33	196 bushels	19,530	273
1953	Y103A	do	21.9	4.97	143 bushels	15,600	319
Average	Y102C		20.3	4.60	114 bushels	12,858	397
	Y103A		22.4	5.08	114 bushels	13,400	387
Wheat:							
1942	Y102C	Apr.–June	12.4	2.81	32 bushels	3,720	755
1942	Y103A	do	12.0	2.72	35 bushels	4,100	663
1946	Y102C	do	14.2	3.22	38 bushels	4,880	660
1946	Y103A	do	14.0	3.17	36 bushels	4,160	762
1950	Y102C	do	12.9	2.91	43 bushels	6,380	456
1950	Y103A	do	14.5	3.29	43 bushels	6,580	500
1954	Y102C	do	14.0	3.17	54 bushels	6,040	525
1954	Y103A	do	14.7	3.33	48 bushels	5,480	608
Average	Y102C		13.4	3.03	42 bushels	5,255	599
	Y103A		13.8	3.13	40 bushels	5,080	622

Meadow, first year:							
1943	Y102C	Apr.–Aug.	19.4	4.40	2.36 tons	4,720	932
1943	Y103A	do	20.3	4.60	1.67 tons	3,340	1,377
1947	Y102C	do	21.7	4.91	2.44 tons	4,880	1,006
1947	Y103A	do	21.2	4.80	1.95 tons	3,900	1,231
1951	Y102C	do	21.6	4.89	2.70 tons	5,400	906
1951	Y103A	do	22.2	5.03	2.27 tons	4,540	1,108
1955	Y102C	do	[3] 27.0	6.12	5.97 tons	11,940	513
1955	Y103A	do	24.6	5.57	4.43 tons	8,860	629
Average	Y102C		22.4	5.08	3.37 tons	6,735	820
	Y103A		22.1	5.00	2.58 tons	5,160	1,086
Meadow, second year:							
1944	Y102C	Apr.–Aug.	18.7	4.23	1.50 tons	3,000	1,410
1944	Y103A	do	20.5	4.65	1.50 tons	3,000	1,550
1948	Y102C	do	25.9	5.87	3.10 tons	6,200	947
1948	Y103A	do	26.3	5.96	3.80 tons	7,600	784
1952	Y102C	do	24.0	5.44	2.64 tons	5,280	1,030
1952	Y103A	do	25.0	5.65	3.36 tons	6,720	841
Average	Y102C		22.9	5.18	2.41 tons	4,833	1,129
	Y103A		23.9	5.42	2.89 tons	5,773	1,060

[1] Computed on an acre basis from the lysimeter data.
[2] Includes 5.82 inches of irrigation water.
[3] Includes 5.32 inches of irrigation water.

the last hay harvest. These values may be obtained from the graphs of accumulated ET—CA (figs. 9, 13, and 17). There are no graphs for 1943. In 1951, for example, ET—CA for Y102C was 17.6 inches for the period April 1 to July 14. With a yield of 2.70 tons per acre, the water-use efficiency value for this short-term period was 854 pounds of water to produce a pound of crop, instead of 906 pounds, the value for the entire 5-month period. For Y103A, the short-term efficiency value was 1,046 pounds of water per pound of crop produced, instead of 1,108 pounds of water, the 5-month value. The short-term values for both Y102C and Y103A were 94 percent of the 5-month values.

With irrigation on Y102C in 1955, water use reached a total of 27.0 inches. Crop yield was 5.97 tons per acre, the highest for any first-year meadow. Water-use efficiency with irrigation was 513 pounds of water per pound of crop, the best first-year meadow value. For the season from April 1 to the last cutting of hay on July 22, consumptive use on irrigated lysimeter Y102C totaled 20.2 inches of water and efficiency of use was 383 pounds of water per pound of hay. This is 74 percent of the 5-month figure of 513 pounds.

Water-use values for second-year meadow (table 20) for the 5-month period April through August ranged from 18.7 to 26.3 inches. Crop-yield values ranged from 1.50 to 3.80 tons per acre. Water-use efficiency for the 5-month period ranged from 784 to 1,550 pounds of water per pound of crop. Water-use efficiency in 1952 for the season April 1 to the last cutting of hay was 754 pounds of water for Y102C, or 73 percent of the 5-month value of 1,030 pounds, and 841 pounds for Y103A, or 73 percent of the 5-month value of 841 pounds.

A study of the crop use of water by semimonthly periods (figs. 23, 24, 25, and 26) shows that the rate of water consumption varied considerably throughout the growing season. For example, depletion of soil-water supplies (consumptive use) by corn, without irrigation, was greatest in July (fig. 23). Ordinarily, this value exceeded the amount of rainfall. In fact, depletion of soil moisture during July was so great that supplies in August were not enough to meet the demand. Without irrigation ET—CA was less in August and September than in July, as indicated by the 1941, 1945, and 1949 data for Y102C and Y103A and the 1953 data for Y103A. Irrigation on Y102C in 1953 resulted in continued high rate of water consumption until the end of August—about 3.5 inches for the period August 16–31 as compared with less than 2 inches on unirrigated lysimeter Y103A. A picture of the difference between these two lysimeters in available moisture can be obtained from the top graphs of figure 15.

Evapotranspiration from cornland in May and early June usually was low—about 2 inches per half month. As there was very little leaf area in this early season, transpiration was low. Evaporation was high from a wet soil surface and low from a dry soil surface. The difference between ET—CA data for nearly bare cornland (Y102C) and for legume-grass (Y101D) is shown by the wide divergence of their soil-moisture curves in May and June 1949 (fig. 11) and in late May and June 1953 (fig. 15), and by the striking difference between the ET—CA graphs in figures 23, 24, 25.

Wheat used water most rapidly in late May and early June (fig. 24). Water was removed from soil pores by evapotranspiration faster from wheatland than from cornland prior to June 15. Water needs for wheat

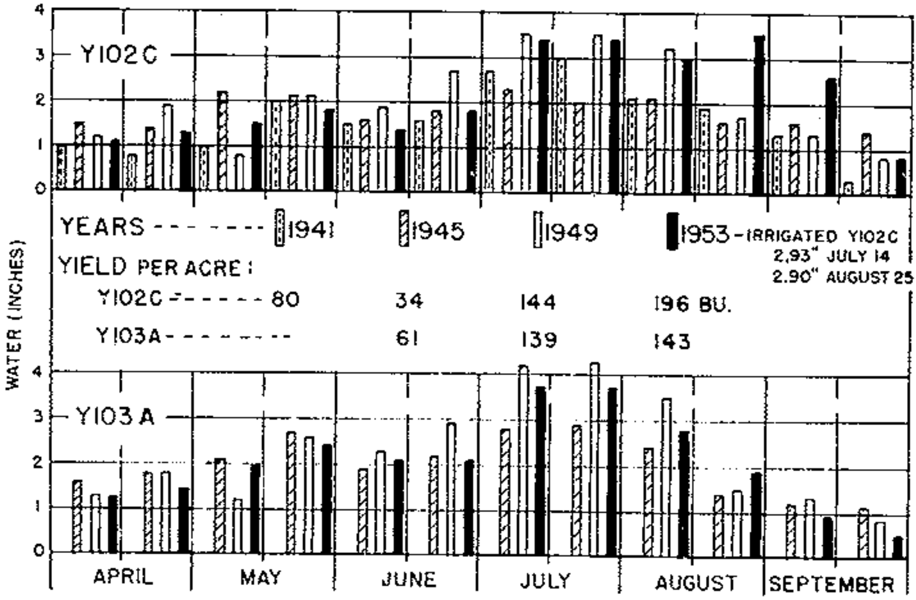

FIGURE 23.—Semimonthly evapotranspiration (ET − CA) from cornland lysimeters Y102C and Y103A for 1941, 1945, 1949, and 1953.

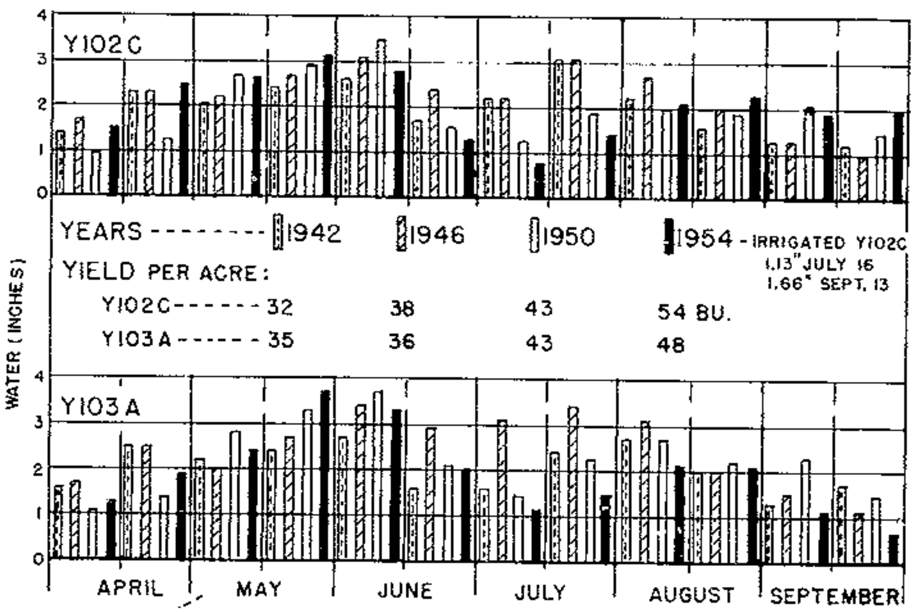

FIGURE 24.—Semimonthly evapotranspiration (ET − CA) from wheatland lysimeters Y102C and Y103A for 1942, 1946, 1950, and 1954.

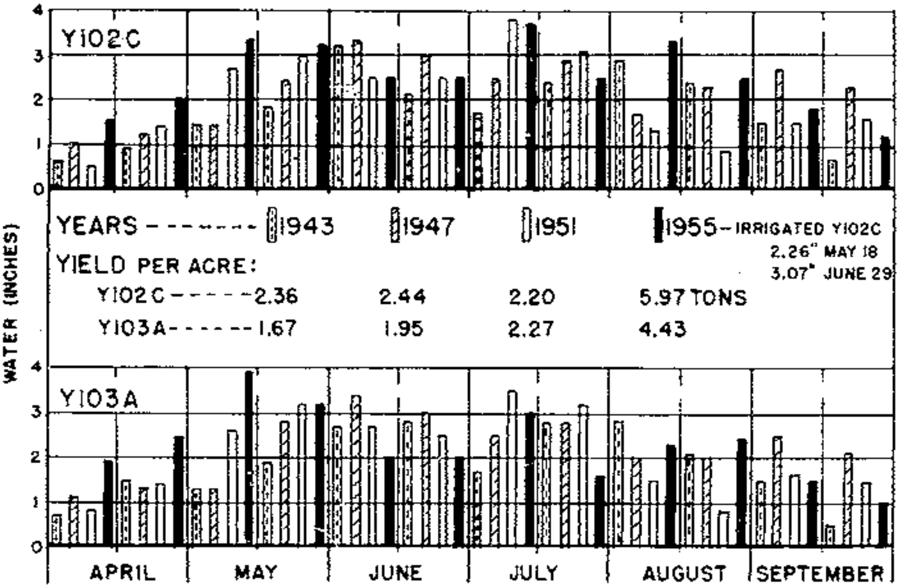

FIGURE 25.—Semimonthly evapotranspiration (ET—CA) from first-year meadow lysimeters Y102C and Y103A for 1943, 1947, 1951, and 1955.

diminished after the middle of June. This is the ripening period. Following wheat harvest and the removal of straw the new meadow of timothy, red clover, and alfalfa put on rapid growth. Consumptive use of water increased somewhat as the leaf area increased in late July and August.

Water-use data by first-year meadow for lysimeters Y102C and Y103A for 4 years are shown in figure 25. Vegetation was mostly timothy, red clover, and small alfalfa plants. Water consumption was greatest in the first half of June. Hay cutting in June reduced the demand for water. Water use increased in July as a result of leaf-area growth and then decreased early in August after the second cutting of hay.

Irrigation on Y102C in July and August 1953 resulted in continued high use of water until late September. The contrast between ET—CA data (fig. 23) for irrigated lysimeter Y102C and for unirrigated lysimeter Y103A in August and early September is striking. ET—CA in late August was about 3.5 inches for Y102C and less than 2 inches for Y103A.

Without irrigation there appeared to be little or no difference in consumptive-use values for lysimeters Y102C and Y103A, when the surfaces were completely covered with vegetation such as meadow. However, when there was very little vegetative cover, ET—CA appeared to be greater for the wetter soil of Y103A than for the better-drained soil of Y102C.

Water-use data by second-year meadow appear in figure 26. Like the data for first-year meadow (fig. 25), the period of maximum consumptive use extended from the last half of May through July. These values were generally lower in 1944 than for the same period in 1948 or 1952. There was no alfalfa in 1944, and the vegetative cover was mostly shallow-rooted grass and weeds. Yield was about 1.5 tons per acre. Vegetative cover in 1948 and 1952 consisted of a good stand of alfalfa and yielded over 3 tons per acre. The deeper roots of the alfalfa may account for greater consumptive use in these 2 years. With a dry soil surface, these plants could get water when the shallow-rooted plants in 1944 could not.

For certain design purposes, such as irrigation systems, it may be necessary to know the maximum rate of ET—CA for periods of a week or 10 days. Monthly or semimonthly values do not provide the necessary information. Apparent in table 21 are the differences between maximum consumptive-use rate and the monthly average rate. For example, in August 1953 the maximum-use rate for the corn lysimeter was 0.36 inch per day and the monthly average was 0.22. An irrigation system designed to meet a water-use figure of 0.22 inch per day would fail to produce the maximum crop when confronted with the demand rate of 0.36 inch per day. In some months the average water-use rate and maximum demand rate for short periods were almost the same.

Moisture values for 40 inches of soil in table 21 represent an approximate average for the month. They are given to help the reader see how the consumptive-use values drop off in August and September with lower available moisture. This is not always the case, as values of moisture in 40 inches of soil may not represent the moisture available to the plant. Sometimes available moisture in the top foot or two of soil was nearly exhausted, causing reduced yields and lower values of ET—CA, when there was enough moisture below the 24-inch depth to give a fairly high moisture average for the entire 40-inch profile.

Evapotranspiration (ET—CA) compared to water-surface evaporation and atmometer evaporation

Lysimeter studies provide valuable information on water use by

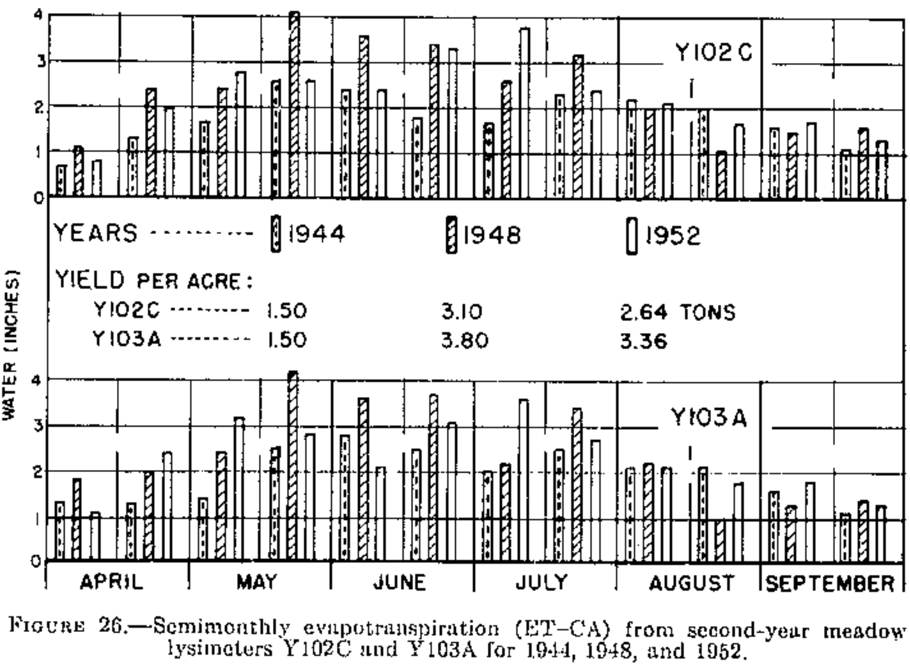

FIGURE 26.—Semimonthly evapotranspiration (ET–CA) from second-year meadow lysimeters Y102C and Y103A for 1944, 1948, and 1952.

TABLE 21.—*Average daily consumptive use of water by crops on lysimeters Y102C and Y103A, for maximum 10-day period and for the month, May–September, 1942–55*

Lysimeter, crop, and year	Average per day in May			Average per day in June			Average per day in July		
	Consumptive use		Soil moisture [1]	Consumptive use		Soil moisture [1]	Consumptive use		Soil moisture [1]
	Maximum 10 days	Month		Maximum 10 days	Month		Maximum 10 days	Month	
Y102C:									
Wheat to meadow—	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1942	0. 16	0. 13	11. 5	0. 21	0. 15	11. 5	0. 22	0. 17	10. 0
1946	. 18	. 15	10. 0	. 23	. 19	10. 0	. 23	. 17	11. 0
1950	. 20	. 17	11. 0	. 26	. 17	11. 0	. 12	. 10	11. 0
1954	. 22	. 19	10. 5	. 22	. 14	6. 0	. 10	. 07	[2] 6. 0
Meadow, first year—									
1943	. 13	. 11	13. 5	. 23	. 18	12. 5	. 18	. 13	10. 5
1947	. 23	. 12	13. 5	. 28	. 20	12. 0	. 25	. 18	9. 0
1951	. 22	. 18	10. 5	. 21	. 17	9. 0	. 26	. 24	9. 0
1955	. 21	. 21	[2] 9. 5	. 17	. 16	[2] 7. 5	. 26	. 20	7. 5
Meadow, second year—									
1944	. 17	. 14	9. 5	. 18	. 14	8. 5	. 15	. 14	7. 0
1948	. 27	. 22	8. 0	. 25	. 22	5. 0	. 21	. 18	5. 0
1952	. 23	. 18	10. 0	. 30	. 20	7. 0	. 26	. 20	6. 0
Corn—									
1945	. 15	. 13	12. 0	. 16	. 11	10. 5	. 17	. 14	9. 5
1949	. 15	. 09	12. 5	. 19	. 15	11. 0	. 26	. 23	10. 0
1953	. 13	. 11	14. 0	. 14	. 11	12. 0	. 25	. 22	[2] 12. 0
Y103A:									
Wheat to meadow—									
1942	. 20	. 15	11. 5	. 22	. 14	13. 5	. 15	. 13	11. 5
1946	. 18	. 16	14. 0	. 24	. 21	14. 0	. 25	. 22	14. 0
1950	. 22	. 19	14. 0	. 26	. 19	14. 0	. 12	. 12	13. 0
1954	. 23	. 20	14. 0	. 26	. 18	10. 0	. 10	. 08	9. 0

Meadow, first year—									
1943	.13	.10	12.0	.22	.15	10.5	.18	.15	9.0
1947	.22	.13	16.0	.28	.22	15.5	.23	.16	12.0
1951	.23	.18	13.0	.20	.18	11.5	.25	.21	11.5
1955	.24	.23	13.0	.14	.13	10.0	.20	.15	9.0
Meadow, second year—									
1944	.16	.12	13.0	.21	.17	10.0	.15	.15	8.0
1948	.29	.22	12.0	.26	.25	8.0	.23	.18	7.0
1952	.26	.20	13.0	.24	.18	10.0	.23	.20	10.0
Corn—									
1945	.19	.15	15.0	.19	.15	14.0	.21	.19	12.5
1949	.17	.12	16.0	.21	.18	14.0	.33	.29	14.0
1953	.17	.14	16.0	.18	.14	14.0	.25	.23	12.0

Lysimeter, crop, and year	Average per day in August			Average per day in September			Yield per acre
	Consumptive use		Soil moisture [1]	Consumptive use		Soil moisture [1]	
	Maximum 10 days	Month		Maximum	Month		
Y102C:							
Wheat to meadow—	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	
1942	0.16	0.11	8.0	0.09	0.08	8.0	32 bushels.
1946	.22	.16	9.0	.10	.07	7.0	38 bushels.
1950	.16	.13	9.5	.16	.12	10.5	43 bushels.
1954	.16	.14	7.5	.15	.13	[2] 7.0	54 bushels.
Meadow, first year—							
1943	.20	.18	11.5	.12	.07	9.0	2.4 tons.
1947	.19	.13	8.0	.19	.17	7.0	2.5 tons.
1951	.10	.07	5.5	.13	.11	6.0	2.7 tons.
1955	.20	.19	5.0	.13	.10	5.0	6.0 tons.
Meadow, second year—							
1944	.16	.14	6.0	.12	.10	6.5	1.5 tons.
1948	.17	.10	4.5	.11	.09	4.0	3.1 tons.
1952	.16	.13	5.0	.11	.10	4.5	2.6 tons.

See footnotes at end of table.

TABLE 21.—*Average daily consumptive use of water by crops on lysimeters Y102C and Y103A, for maximum 10-day period and for the month, May-September, 1942-55*—Continued

Lysimeter, crop, and year	Average per day in August			Average per day in September			Yield per acre
	Consumptive use		Soil moisture [1]	Consumptive use		Soil moisture [1]	
	Maximum 10 days	Month		Maximum	Month		
Y102C—Continued							
Corn—	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	
1945	.13	.12	7.0	.11	.10	9.0	34 bushels.
1949	.23	.15	9.0	.10	.07	7.5	151 bushels.
1953	.36	.22	[2] 11.0	.22	.11	8.5	196 bushels.
Y103A:							
Wheat to meadow—							
1942	.18	.15	10.0	.08	.07	9.5	35 bushels.
1946	.20	.16	12.5	.11	.09	9.0	36 bushels.
1950	.18	.16	11.0	.18	.13	14.0	43 bushels.
1954	.15	.14	10.0	.10	.06	9.5	48 bushels.
Meadow, first year—							
1943	.21	.15	8.5	.14	.07	7.0	0.5 ton.
1947	.20	.13	10.0	.19	.15	10.0	2.0 tons.
1951	.13	.08	9.5	.13	.10	9.0	2.3 tons.
1955	.16	.15	8.5	.09	.09	7.5	4.4 tons.
Meadow, second year—							
1944	.15	.14	7.0	.10	.09	7.5	0.5 ton.
1948	.18	.10	7.0	.11	.09	6.5	3.8 tons.
1952	.16	.15	7.5	.13	.10	8.0	3.4 tons.
Corn—							
1945	.18	.13	9.5	.09	.08	13.0	61 bushels.
1949	.28	.16	12.5	.10	.07	11.0	148 bushels.
1953	.18	.15	10.0	.06	.04	8.0	143 bushels.

[1] Moisture (inches of water) in 40 inches of soil. [2] Irrigated.

crops in the Coshocton area. There are only a very few lysimeters over the country and none are developed for hydrologic studies to the extent of those at the Coshocton station. There is therefore a need to develop a relationship between ET—CA and some type of hydrologic measurement for which records are commonly available in this and other States. If such a relationship can be developed with reasonable accuracy, perhaps the Coshocton data can be adapted to the commonly-available hydrologic data for use in regions outside the Coshocton area.

With this in mind, the lysimeter ET—CA values have been correlated with data from evaporation pans and from white atmometer bulbs (figs. 27, 28, 29, 30, 31, 32, 36, and 37). Evaporation of water from both the pan and the atmometer bulb represents an integrated measure of the forces causing the transfer of water from liquid form to vapor form in the atmosphere. These forces are for the most part comprised of solar radiation, relative humidity of the air near the ground, wind movement, and air and water temperature. Data are commonly available for all these except solar radiation. The United States Weather Bureau maintains and publishes data from evaporation pans at many locations in this country. Atmometer data can be obtained easily and at very low cost.

The evaporation pan used at Coshocton (BPI pan) was 6 feet in diameter and 2 feet deep. It was sunk in the ground to within 4 inches of the top of the pan, and the water surface was maintained at about ground-surface level. Data from this type of pan are not common over the country. The United States Weather Bureau evaporation pan, which is most generally used, differs from the pan used in these studies and its evaporation values are higher. A coefficient of 0.75 can be used to adjust values obtained with the United States Weather Bureau pan to values used in this study.

An attempt was made to relate ET—CA values to daily evaporation-pan values. The result was a wide scattering of points. The next step, and the one adopted, was to relate accumulated daily ET—CA values to accumulated daily evaporation-pan values and accumulated daily atmometer values for the growing season, April through September. These curves are termed "mass curves."

Fairly straight lines appeared in sections of these mass curves, indicating periods of uniform water loss as determined by the different methods. For example, in figure 29, all three lines are nearly straight and appear to have about the same slope from about May 15 to June 10. This means that ET—CA for wheat on lysimeters Y102C and Y103A was at the same rate as pan evaporation. The slope of all three curves diminished from June 10 until about June 25. After that, the mass curve for the evaporation pan resumed its steep slope, indicating that the energy forces causing evaporation and transpiration after June 25 were rather high. The ET—CA curves, however, continued at a lesser slope as water use by wheat was at a fairly low rate from June 25 to about July 20. This was the period of wheat ripening and harvest, and before the new meadow had developed much leaf area. After July 20, the new meadow on Y103A consumed water at nearly the same rate as the evaporation-pan rate. On Y102C, the ET—CA rate was about 90 percent of the evaporation-pan rate and the ET—CA rate for Y103A. The latter usually has more soil moisture than Y102C.

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EVALUATION OF AGRICULTURAL HYDROLOGY BY MONOLITH LYSIMETERS 1944-55
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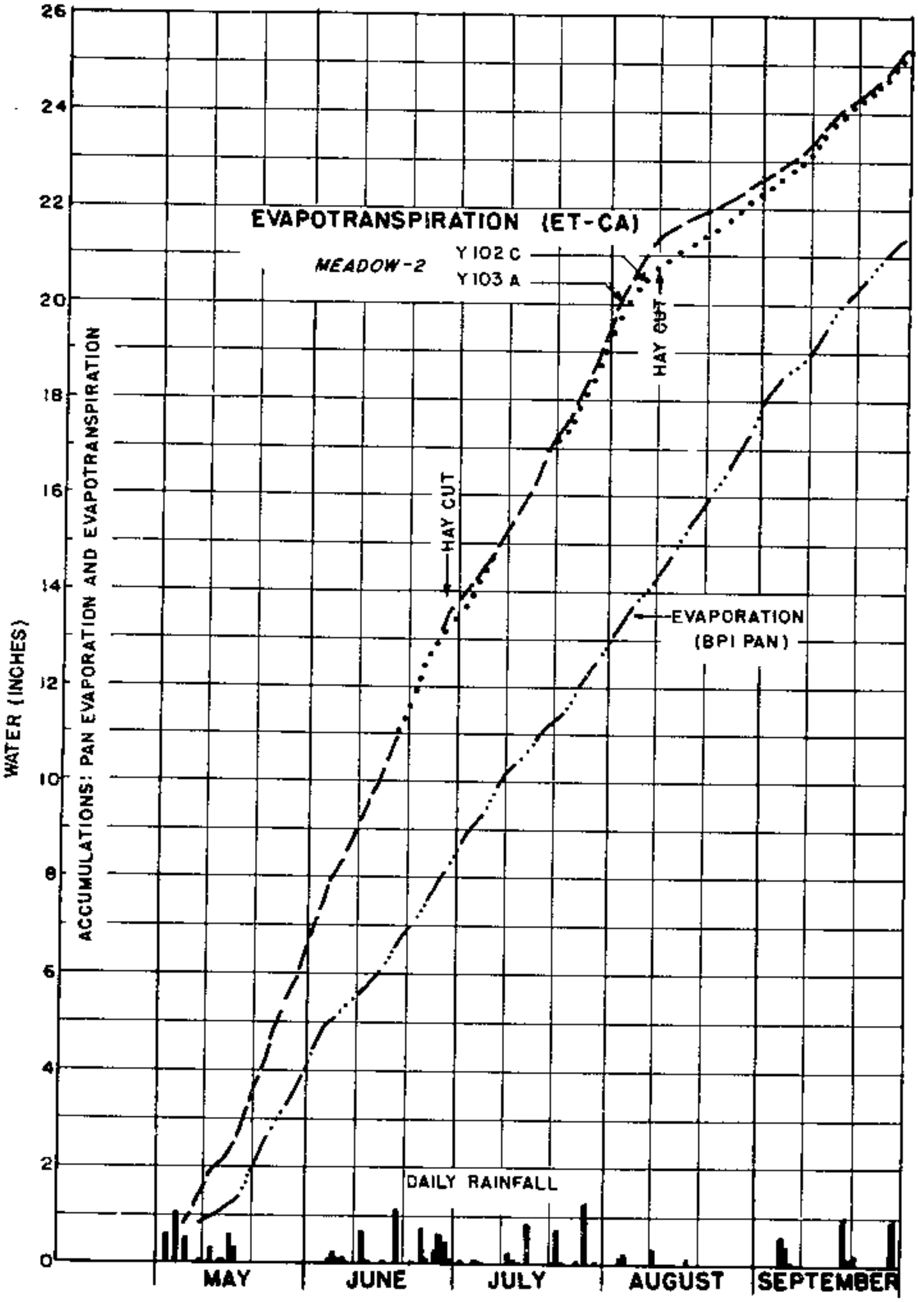

FIGURE 27.—Daily rainfall and accumulation of daily (1) evapotranspiration from lysimeters Y102C and Y103A and (2) pan evaporation, May–September 1948.

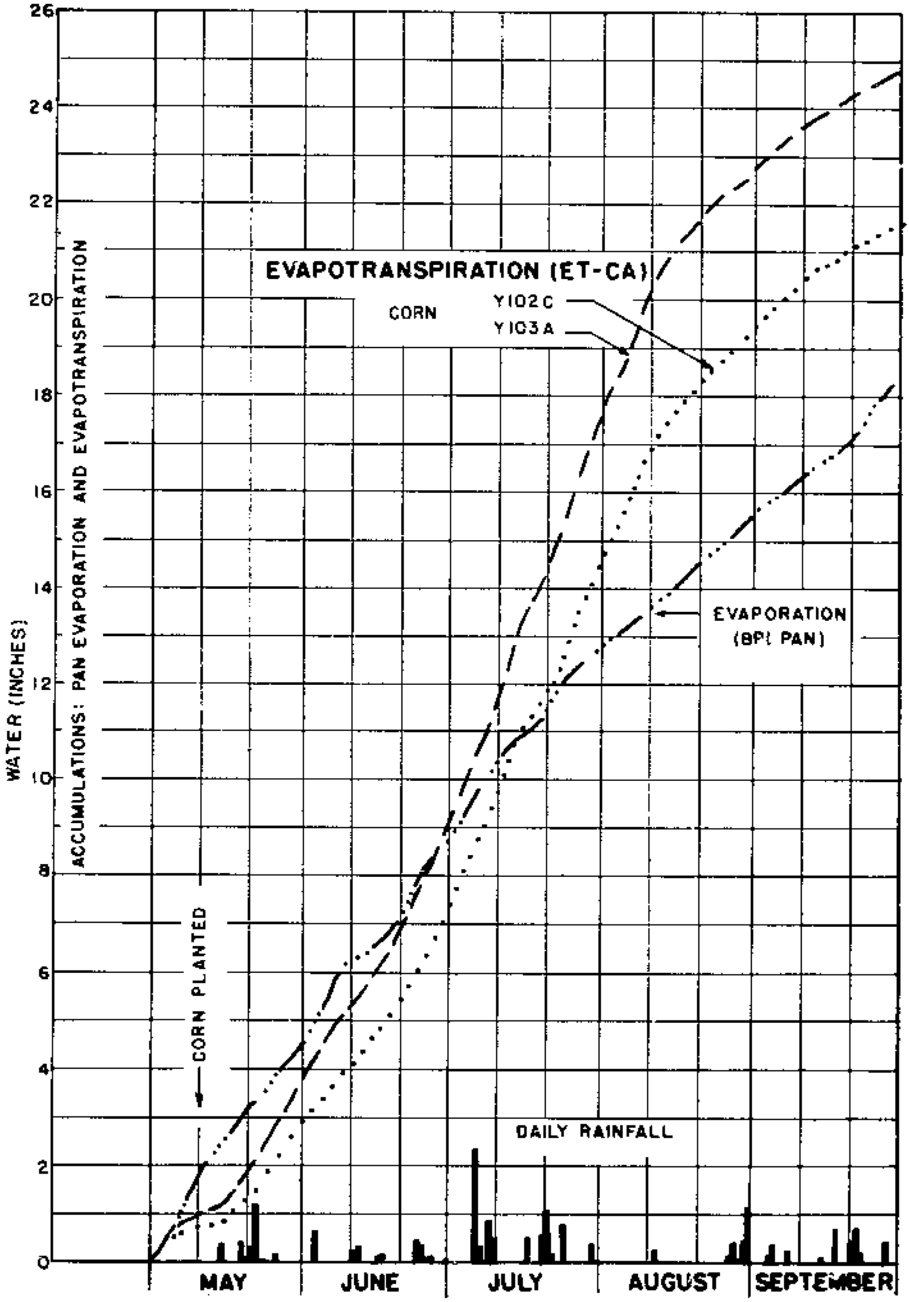

FIGURE 28.—Daily rainfall and accumulation of daily (1) evapotranspiration from lysimeters Y102C and Y103A and (2) pan evaporation, May–September 1949.

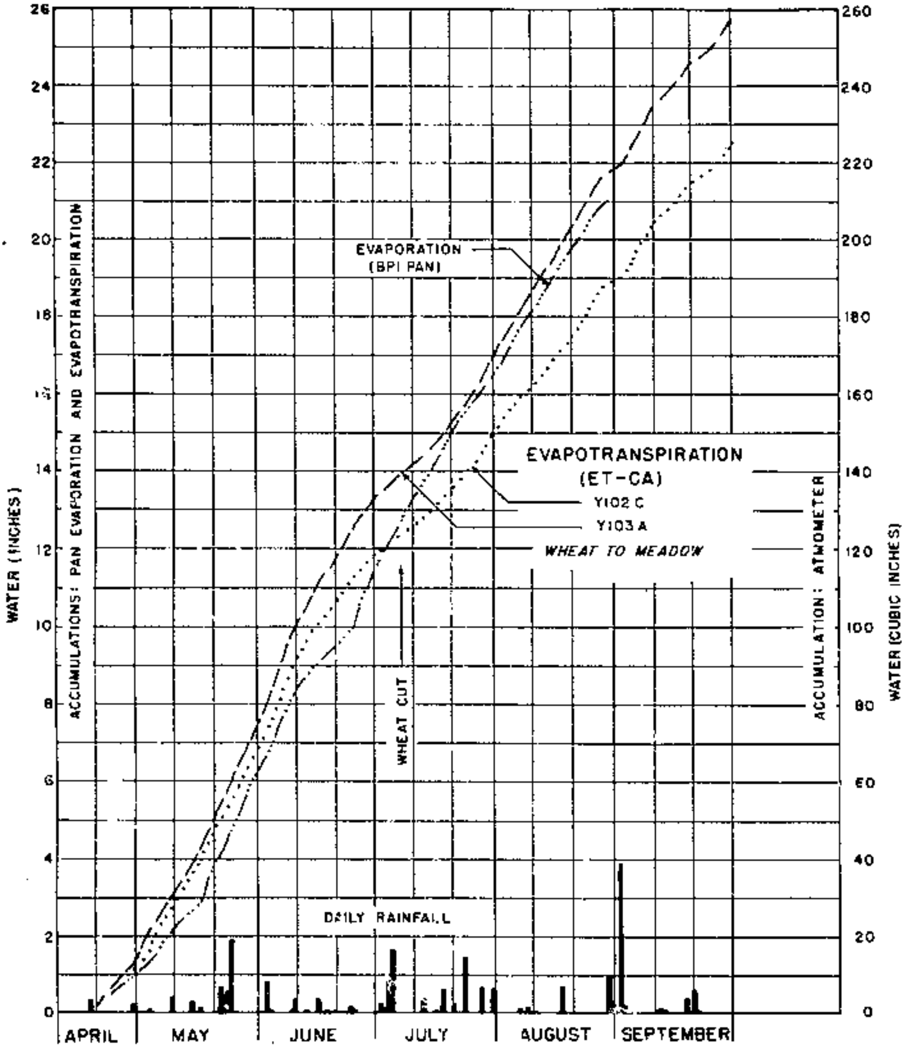

FIGURE 29.—Daily rainfall and accumulation of daily (1) evapotranspiration from lysimeters Y102C and Y103A and (2) pan evaporation, April–September 1950.

Evapotranspiration rates exceeded evaporation-pan rates whenever the slope of the mass curve of the former was greater than the latter. This situation prevailed in 1950 (fig. 29) from April 20 to May 18 and from June 10 to June 25, but the difference was not very large. Consumptive-use rates by first-year meadow in 1951 (fig. 30) exceeded evaporation-pan rates by about 40 percent continuously from May 12 until the second cutting of hay. For a short period after the first cutting of hay the evaporation-pan and ET—CA rates were about the same.

Consumptive use of water by second-year meadow (figs. 27 and 31) exceeded pan evaporation and atmometer evaporation at times throughout the growing season, but by much less amounts than for first-year meadow (fig. 30). There were many periods in 1952 (fig. 31) when the mass curves were parallel, i. e., the rates of water loss were essentially the same. Atmometer-bulb data first became available in 1952. Its mass curve roughly parallels the evaporation-pan mass curve until September, after which the atmometer mass curve is greater. This also occurred in 1953 (fig. 32). In 1954 (fig. 36) and in 1955 (fig. 37) the slope of the atmometer mass curve generally exceeded that of the evaporation-pan from late May through September.

In 1953 (fig. 32), water-loss rates in May were about the same from all four sources. In July and August, the evaporation-pan rates and the atmometer rates were nearly the same, but crop use of water from these two measures of

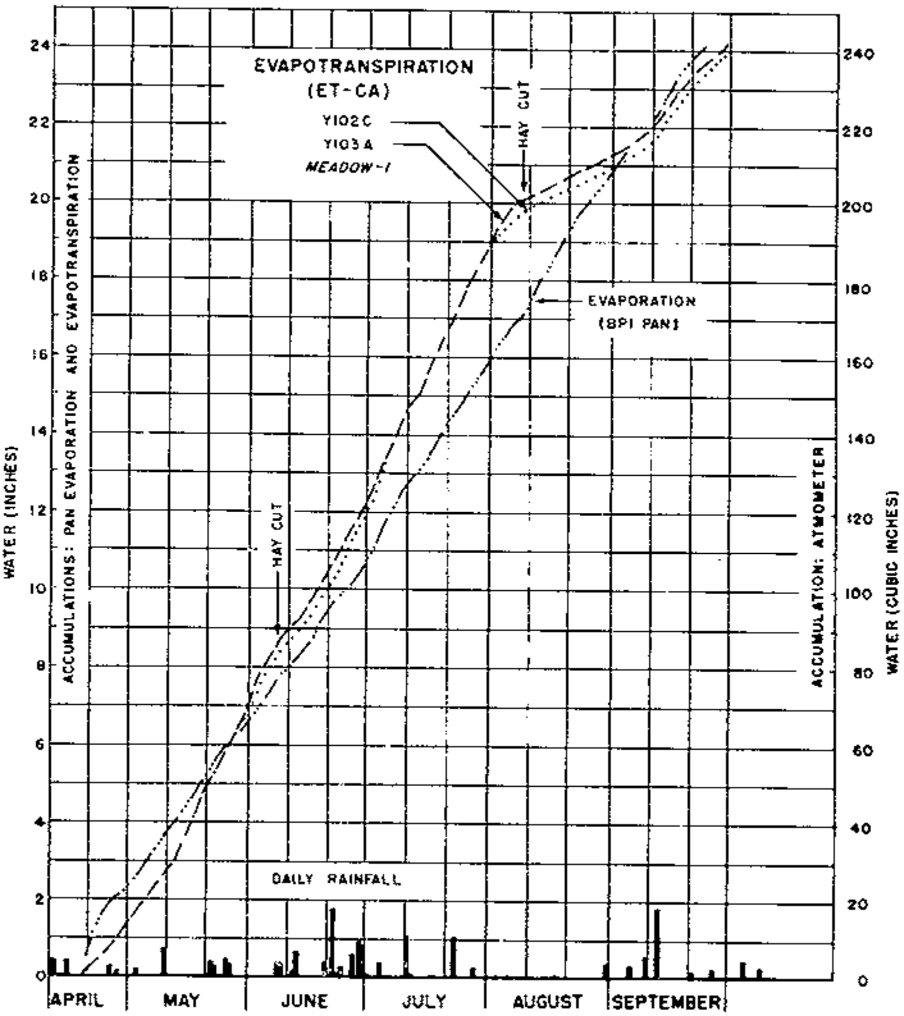

FIGURE 30.—Daily rainfall and accumulation of daily (1) evapotranspiration from lysimeters Y102C and Y103A and (2) pan evaporation, April–September 1951.

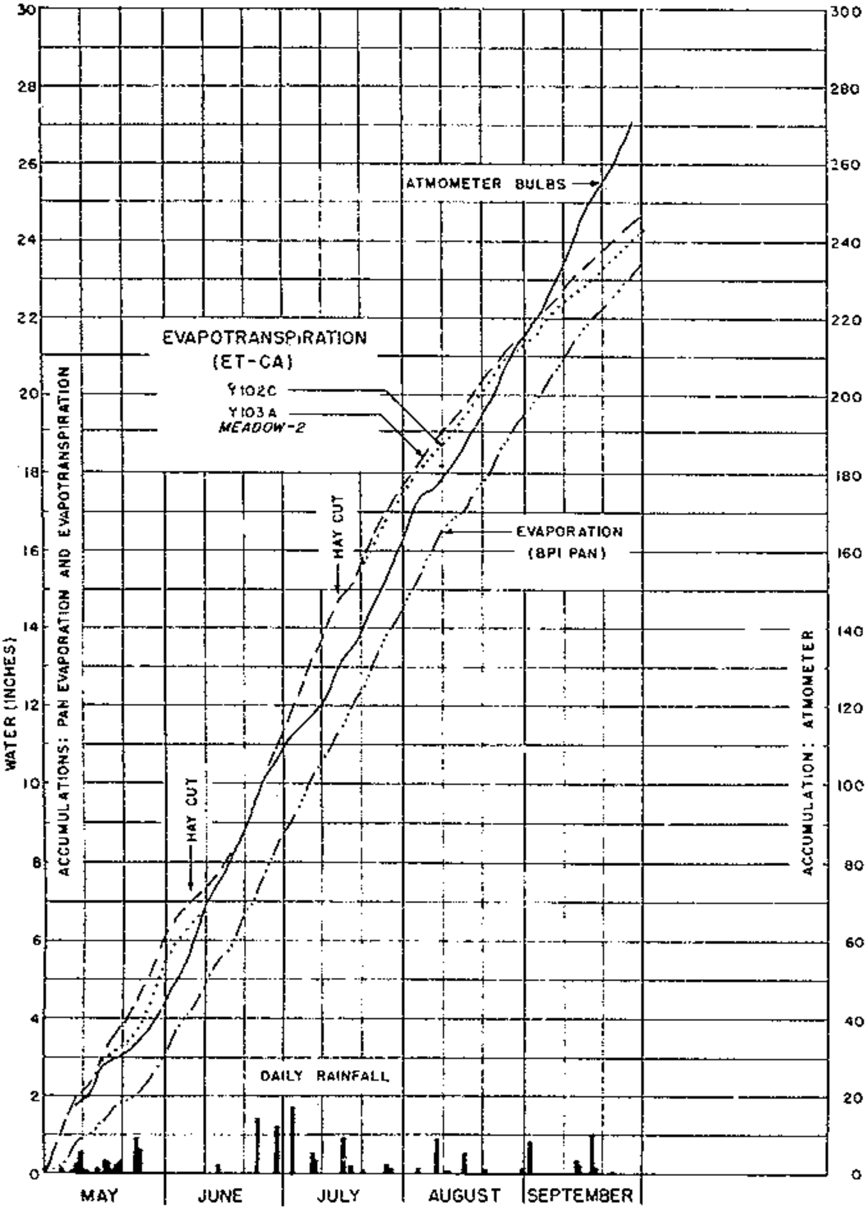

FIGURE 31.—Daily rainfall and accumulation of daily (1) evapotranspiration from lysimeters Y102C and Y103A, (2) pan evaporation, and (3) water evaporated from atmometer bulbs, April–September 1952.

the evaporating forces differed noticeably. In June when ET—CA values were small, as indicated by the lesser slope of the mass curves for Y102C and Y103A, the corn plant had developed only a little leaf area. In July and August, however, leaf area of the corn plant was large and the rate of water use was great, as indicated by the steepness of the mass curves for Y102C and Y103A. In fact the slope of these mass curves exceeded the slope of the evaporation-pan and atmometer mass curves by 40 percent for a period of nearly 2 months

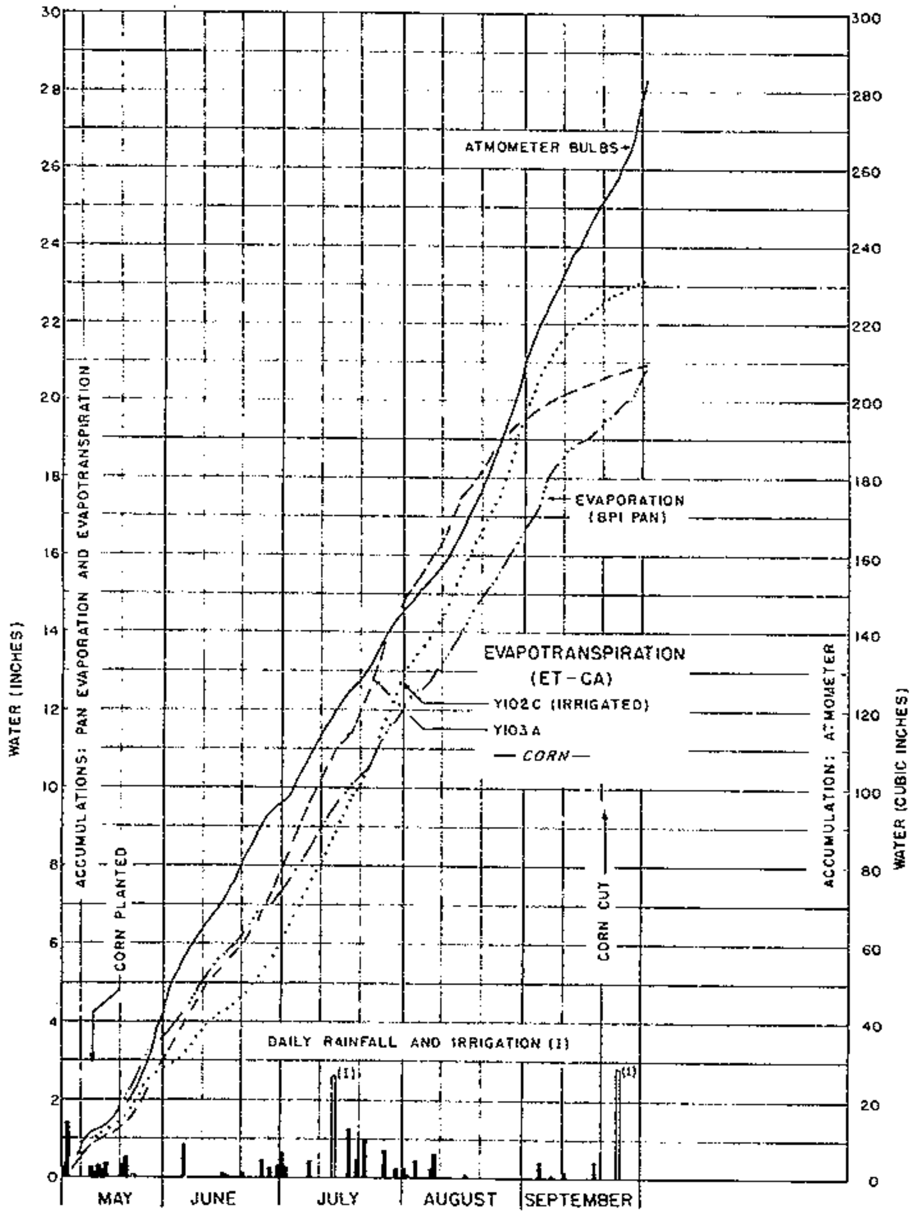

FIGURE 32.—Daily rainfall and accumulation of daily (1) evapotranspiration from lysimeters Y102C and Y103A, (2) pan evaporation, and (3) water evaporated from atmometer bulbs, April–September 1953.

Near the end of August the rate of water use by corn on Y102C (irrigated) and the atmometer rate were about the same.

In 1953 the corn on Y102C was irrigated and that on Y103A was not. The mass curves of evapotranspiration (fig. 32) for lysimeters Y102C and Y103A were parallel from late June to about August 10. After this date the ET—CA mass curve for Y103A dropped off fast, whereas that for Y102C continued at a high rate until the corn matured, about September 5. Yield difference (table 20) between these two lysimeters was 53 bushels per acre.

Evapotranspiration and pan evaporation can be compared by the double mass-curve plotting, as shown in figures 33, 34, and 35 The accumulated value of water use by crops is plotted against the accumulated value of pan evaporation. Whenever the double-mass-curve line parallels the *line of equal values,* the rate of water use by crops and pan-evaporation are the same. The slope of the line for May 1952 (fig. 33) is flat, indicating that the rate of water use by crops was greater than pan evaporation. From the first of June to the middle of July, both rates are about equal. After July 15 the pan-evaporation rate exceeded that of crop use. The relationships are shown numerically in figure 33.

In figure 34, the double mass-curve plotting shows the relation-

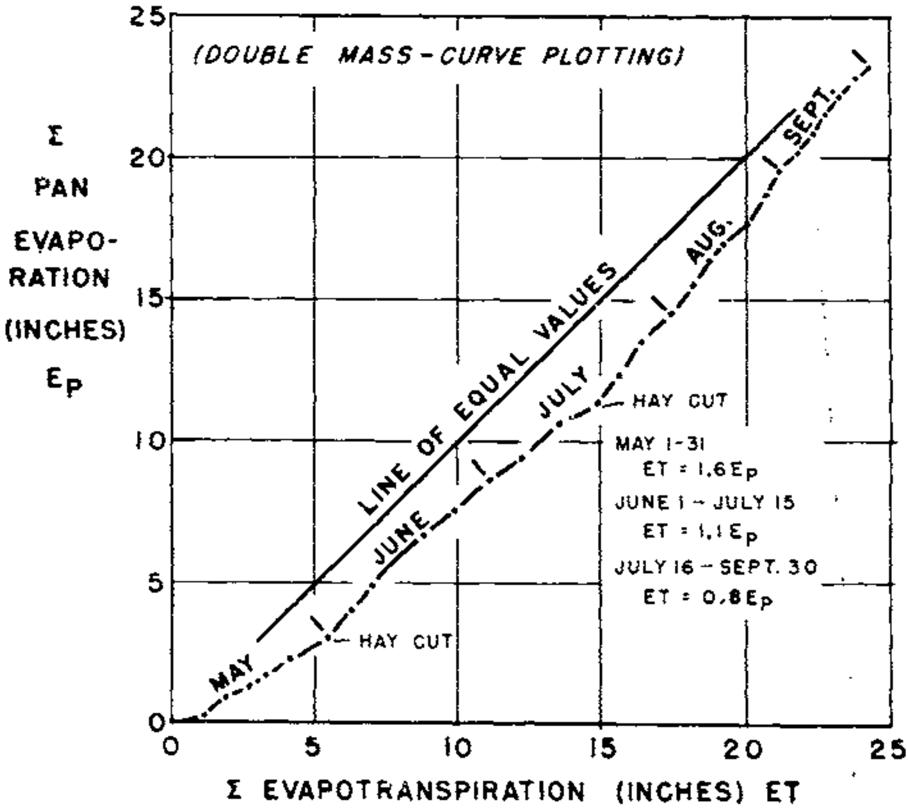

FIGURE 33.—Relation between alfalfa-timothy evapotranspiration and pan evaporation, Y102, 1952.

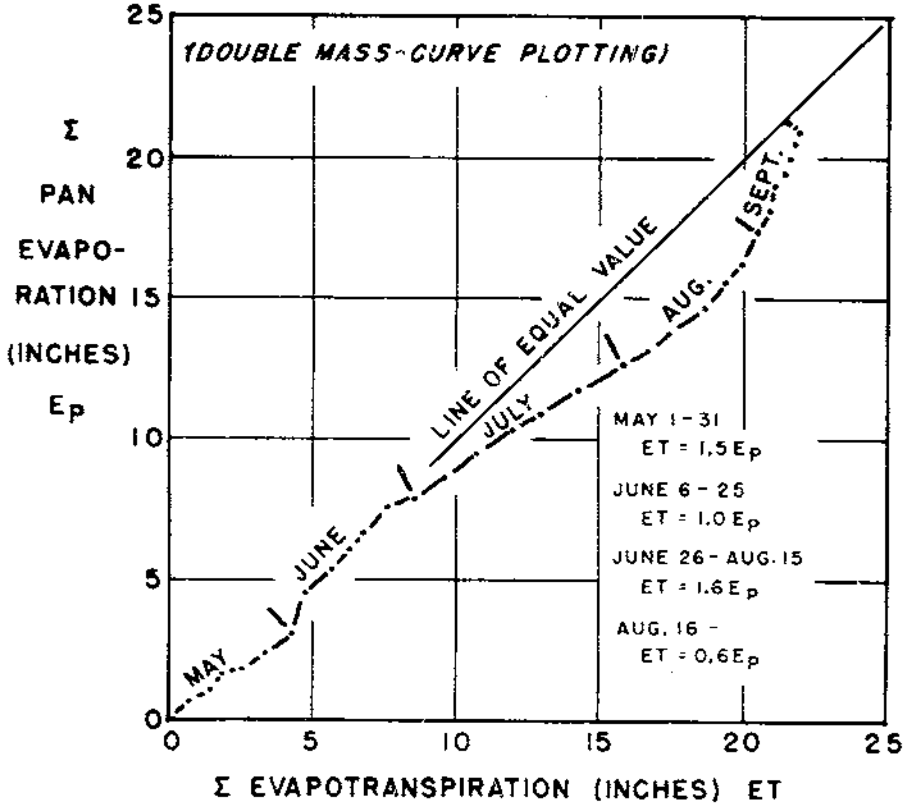

FIGURE 34.—Relation between corn evapotranspiration and pan evaporation, Y103, 1953.

ship between the use of water by corn and pan evaporation. For May, the rate of water use by corn was greater than the evaporation-pan rate. For most of June, the rates were about equal. From late June to mid-August, water use by corn was at a greater rate than pan evaporation. Afterwards water use by co·· dropped off rapidly as a result of insufficient soil moisture.

Water-use data for irrigated corn are compared with evaporation-pan data in figure 35. The general trend of water use is about the same as for unirrigated corn (fig. 34), except that evapotranspiration on Y102C continued at a high rate into September. Relationships are shown numerically for each period of uniform slope.

The effect of wheat maturing, harvest, and growth of new meadow on water use in 1954 is shown in figure 36. These mass curves can be compared with those of the same cropping pattern in 1950 (fig. 29). Wheat yields were from 5 to 11 bushels greater in 1954 than in 1950 (table 20). A similar relationship may be observed by comparing the slope of the mass curves for ET—CA and for the evaporation pan in both years. In 1950 all slopes were about the same while the wheat was growing. In 1954 the slope of the water-use mass curves during wheat growth exceeded the slope of the evaporation-pan mass curves by about 40 percent.

With maturity of wheat, the ET—CA curves dropped off strik-

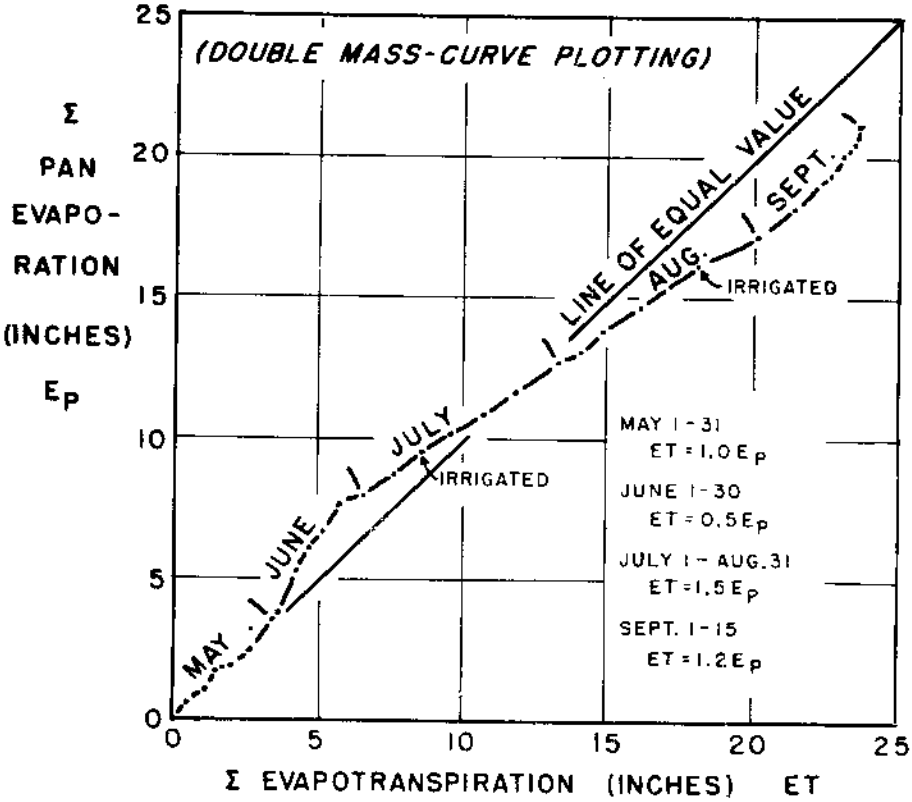

FIGURE 35.—Relation between irrigated corn evapotranspiration and pan evaporation, Y102, 1953.

ingly—more so than in 1950. It is apparent from a glance at the record of daily rainfall for both years (at the bottom of figs. 29 and 36) that 1954 was drier. With less moisture, consumptive use of water by the new meadow plants was less than in 1950. After irrigation in July and as a result of July and August rainfall, the ET−CA curves increased in slope until they had about the same slope as the evaporation-pan curve—as it was in 1950. This means that water use by the new meadow during August and September was at about the same rate as evaporation from the pan. The rate of water use as indicated by the atmometer appears to deviate from the evaporation-pan rate by about the same amount throughout the season.

Use of water by first-year meadow in 1955 (fig. 37) shows about the same relationship to pan evaporation as in 1951 (fig. 30). Its rate was about 40 percent greater than the rate of pan evaporation as long as there was plenty of water (April and May). The slope of the ET−CA curve for Y103A dropped off after June 5 and roughly paralleled the slope of the evaporation-pan curve, which indicates equal rates of water loss. The Y102C curve maintained its steep slope until September except for short periods of lesser slope after hay harvest. Irrigation on Y102C supplied the water needed, a high rate of consumptive use was maintained, and the hay yield increased 1.5 tons per acre (table 20).

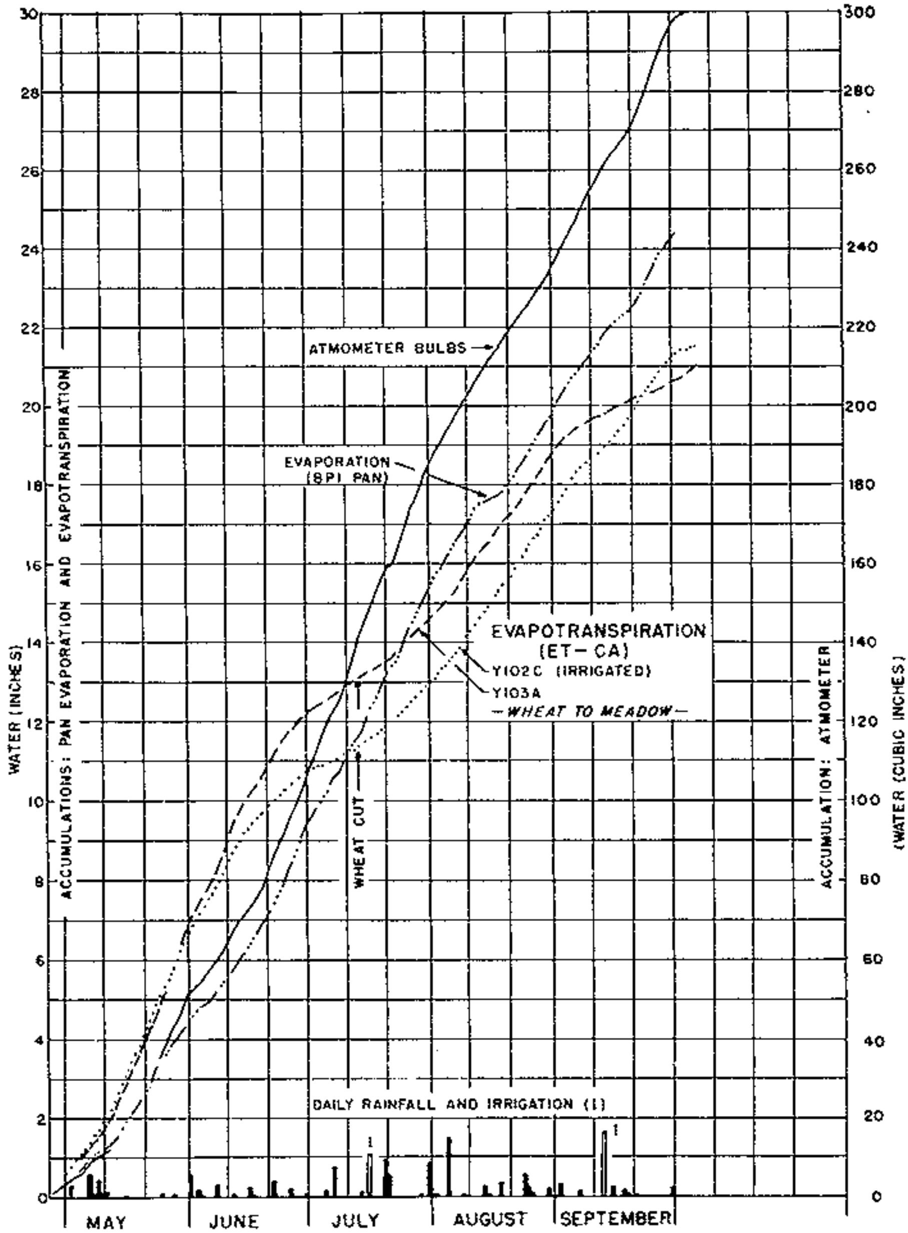

FIGURE 36.—Daily rainfall and accumulation of daily (1) evapotranspiration from lysimeters Y102C and Y103A, (2) pan evaporation, and (3) water evaporated from atmometer bulbs, April–September 1954.

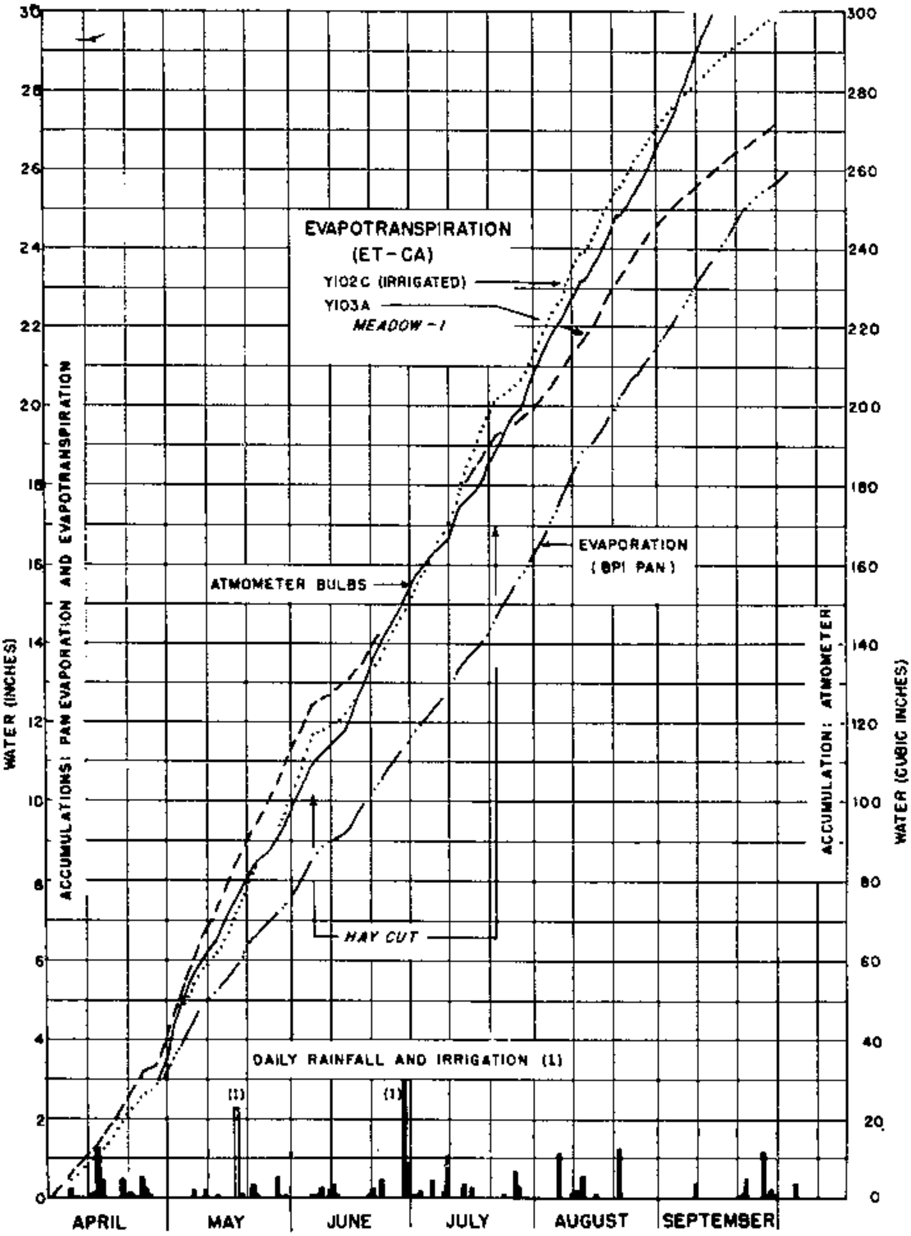

FIGURE 37.—Daily rainfall and accumulation of daily (1) evapotranspiration from lysimeters Y102C and Y103A, (2) pan evaporation, and (3) water evaporated from atmometer bulbs, April–September 1955.

Attention is called to the minor reduction in slope of the ET—CA mass curves at the hay harvest on July 22, 1955 (fig. 37) as compared to a major reduction at the hay harvest on August 8, 1951 (fig. 30). It is likely that rainfall and soil moisture provide the major reason for this difference. In 1951, the period before and after the August hay harvest was so dry there was insufficient moisture to meet the demand—thus the low values of ET—CA. In 1955 there was ample moisture before and after hay harvest to take care of the demand—thus the high values of ET—CA. Evaporation was a large factor in the high values.

Evapotranspiration following night rainfall or heavy dew

The effect on evapotranspiration of dew or rainwater on the vegetation or soil was determined by comparing the evapotranspiration values from wet plant and soil surfaces with similar values from dry surfaces. For wet surfaces, ET values were selected for days following either night rainfall or periods of heavy dew (CA). For dry surfaces, ET values were selected for days following night periods of little or no condensation. These data for lysimeters Y101D and Y102C are given in tables 22, 23, and 24 for 1947, 1948, and 1949, respectively.

In all 3 years very few values were found that could be used for comparative purposes. The criterion for selecting the data was a 3-day period of very little change of vegetation—one of night rainfall, one of heavy dew, and one of little or no dew. The days were not always consecutive.

The general conclusion of the study was that evaporation of moisture on vegetation from the preceding night, whether from rain or dew, substituted for part of the next day's transpiration. For example, in the period May 6–9, 1947 (table 22), ET values for Y102C for each of the 3 days were almost identical. Total ET on May 9 (0.10 inch) was probably made up of 0.06 inch of

TABLE 22.—*Effect of either night rainfall or dew on next day's evapotranspiration, 1947*

Date	Lysimeter [1]	Evapotranspiration following—		
		Night rainfall [2]	Heavy dew [3]	Little or no dew
		Inch	*Inch*	*Inch*
May 6	Y101D			0.12
	Y102C			.11
May 7	Y101D	0.15		
	Y102C	.11		
May 9	Y101D		0.13	
	Y102C		.10	
Aug. 27–29	Y101D		.20	
	Y102C		.21	
Aug. 31	Y101D	.13		
	Y102C	.15		
Sept. 3–4	Y101D			.20
	Y102C			.25

[1] Lysimeter Y101D in grass and Y102C in first-year meadow, legume-grass sod.
[2] Night rainfall preceding evapotranspiration period: May 7=0.20 inch, and August 31=0.74 inch.
[3] Dew preceding evapotranspiration period=0.03 to 0.06 inch.

TABLE 23.—*Effect of either night rainfall or dew on next day's evapotranspiration, 1948*

Date	Lysimeter [1]	Evapotranspiration following—		
		Night rainfall [2]	Heavy dew [3]	Little or no dew
		Inch	*Inch*	*Inch*
July 11	Y101D			0.16
	Y102C			.19
July 13	Y101D	0.15		
	Y102C	.15		
Oct. 4	Y101D			.12
	Y102C			.12
Oct. 14	Y101D		0.12	
	Y102C		.13	
Oct. 18	Y101D	.10		
	Y102C	.11		

[1] Lysimeters Y101D and Y102C in second-year meadow, legume-grass sod.
[2] Night rainfall preceding evapotranspiration period: October 18=1.04 inch.
[3] Dew preceding evapotranspiration period=0.03 to 0.05 inch.

TABLE 24.—*Effect of either night rainfall or dew on next day's evapotranspiration, 1949*

Date	Lysimeter [1]	Evapotranspiration following—		
		Night rainfall [2]	Heavy dew [3]	Little or no dew
		Inch	*Inch*	*Inch*
June 3	Y101D			0.32
	Y102C			.11
June 5	Y101D	0.32		
	Y102C	.25		
June 18	Y101D	.31		
	Y102C	.24		
June 19	Y101D			.28
	Y102C			.21
July 4	Y101D		0.20	
	Y102C		.27	
July 25	Y101D	.32		
	Y102C	.32		
July 26	Y101D			.31
	Y102C			.32
July 27	Y101D			.33
	Y102C			.32
Aug. 7	Y101D		.28	
	Y102C		.26	

[1] Lysimeter Y101D in grass and Y102C in corn.
[2] Night rainfall preceding evapotranspiration period: June 5=0.53 inch, June 18=0.20 inch, July 25=0.74 inch.
[3] Dew preceding evapotranspiration period=about 0.02 inch.

evaporated dew early in the day and 0.04 inch of evapotranspiration from soil moisture. With no dew, as on May 6, all of the ET had to come from the soil water. Dew, therefore, had conserved some soil moisture. When there was little or no dew, larger quantities of soil water were used in the ET process. In other words, the evapotranspiration from vegetated land following nights of little or no dew was mostly transpiration. Furthermore, sizable quantities of the ET from land moistened by CA must have been evaporation. Dew fall, or absorption of water by the soil, or both, therefore, have a soil-moisture conservation value.

Dew or rain had a noticeable effect on evaporation from bare soils. The 1949 data (table 24) showed that evapotranspiration (mostly evaporation) from cornland lysimeter Y102C on June 3 was 0.11 inch. The soil was dry and practically bare. On June 5, following a rainfall of 0.53 inch, evapotranspiration (mostly evaporation) was 0.25 inch—more than double that on June 3. This same rainstorm had no effect on evapotranspiration from grass lysimeter Y101D, as indicated by identical ET values (0.32 inch) for June 3 and 5. Much of the ET from grassland was transpiration by plants.

Evapotranspiration from cornland before and after cultivation

The effect of cultivation in reducing losses of soil moisture by evaporation is a subject that has been widely discussed. An examination of the lysimeter records for the corn years 1941, 1945, 1949, and 1953, particularly evapotranspiration data for several days before and after cultivation, throws some light on this matter. Although there were a total of more than 8 cultivations in these 4 years, only 2 periods—June 1941 and June–July 1949—were suitable for comparison. The other periods were affected by rain and other factors that prevented their use for this purpose.

The daily rate of evapotranspiration from cornland several days before and after these two cultivation periods is given in table 25. In both periods, over 1 inch of rain preceded the initial cultivation. The ground was moist and the evapotranspiration rate high, averaging about 0.25 inch per day. Daily evapotranspiration was less after cultivation on June 23, 1941, than it had been before. Conversely, in 1949, evapotranspiration was greater following cultivation.

The apparent reason for this reversal was the difference in meteorological conditions such as air temperature, moisture, and wind. The integrated effect of these factors as measured by evaporation from the BPI pan is given in table 25 (col. 5). The meteorological potential for evapotranspiration was greater in the period following cultivation on June 23, 1941, than it had been before cultivation. In spite of this greater potential, evapotranspiration from cornland was less following cultivation. Before cultivation, evapotranspiration from lysimeter Y102C was 280 percent of evaporation from the BPI pan. After cultivation the ratio was 95 percent. Likewise, the ratio was 210 percent before cultivation on July 1, 1949, and 142 percent after. Y103A shows similar trends. There are no data from this lysimeter for the 1941 cultivation period.

Cultivation reduced evapotranspiration in both periods. Possibly all the saving was in evaporation. Cultivation might slow up transpiration slightly if many of the plant roots were destroyed by mechanical stirring of the soil.

A comparison between evapotranspiration data from the undisturbed grassland of lysimeter

TABLE 25.—*Effect of cultivation of cornland on evapotranspiration, 1941 and 1949*

Date	Evapotranspiration			Evaporation (BPI pan)	Ratio of evapotranspiration from—			
	Cornland		Grass		Lysimeter Y102C to—		Lysimeter Y103A to—	
	Y102C	Y103A	Y101D		Evaporation from BPI pan	Evapotranspiration Y101D	Evaporation from BPI pan	Evapotranspiration Y101D
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1941	*Inch*	*Inch*	*Inch*	*Inch*	*Percent*	*Percent*	*Percent*	*Percent*
June 17[1]	0.22			0.09				
June 18	.25		0.20	.10				
June 19	.31		.20					
June 20	.32		.20					
Daily average	.28		.20	.10	280	140		
June 23[2]								
June 24	.19		.22	.22				
June 25	.16		.22	.27				
June 26	.24		.11	.16				
June 27	.15		.15	.15				
Daily average	.19		.18	.20	95	105		
1949								
June 28[3]	.20	0.21	.09	.10				
June 29	.26	.29	.12	.12				
June 30	.22	.22	.14	.12				
Daily average	.23	.24	.12	.11	210	190	220	200

July 1 [2]								
July 2	.27	.30	.17	.20				
July 3	.27	.31	.19	.20				
July 4	.27	.31	.20	.18				
July 5	.27	.32	.21	.20				
Daily average	.27	.31	.19	.19	142	153	142	153

[1] 1.54 inches of rain in preceding 4 days.
[2] Corn cultivated this date.
[3] 1.07 inches of rain in preceding 4 days.

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Y101D on the one hand and cornland lysimeters Y102C and Y103A on the other furnished an additional basis for judging the effect of cultivation on moisture conservation. Data in table 25 (col. 9) show the magnitude of this moisture saving.

THE LYSIMETER AS A GUIDE FOR THE DESIGN AND OPERATION OF IRRIGATION SYSTEMS

Irrigation systems designed to supply just enough water to meet the demand of the crop—no more and no less—are likely to result in the most profit and the most efficient use of water resources. One of the factors involved in the design of an irrigation system is the maximum rate of consumptive use of water by the crop. This is an average over a period of a week to 10 days—not the maximum rate for a single day nor the average rate for an entire month.

Data to evaluate this factor have been assembled from the lysimeter records. Maximum 10-day consumptive-use values for 4 crops are given in table 21.

Evapotranspiration (ET — CA) data in this report are for natural soil-moisture supplies for all years on lysimeter Y103A and for years prior to 1953 on lysimeter Y102C. At times for example, in August and September of most years, moisture was so low that consumptive-use values were less than they would have been under conditions of adequate moisture (table 21 and figs. 23, 24, 25, and 26). In good irrigation practice, however, soil-moisture supplies are never allowed to deplete to such low amounts during the growing season. Lysimeter Y102C was therefore irrigated in 1953 and in subsequent years whenever the available moisture in 2 feet of soil depleted to the 50-percent level. Its ET—CA values are higher in August and September 1953, 1954, and 1955 than in former years and are higher than for unirrigated lysimeter Y103A in these 3 years.

The irrigator is becoming increasingly conscious of the need for applying water when it will do the crop the most good. In some sections of the country, the irrigator has developed through experience a knowledge of the feel of the soil to indicate the amount of available moisture and when to irrigate. Some irrigators have found moisture instruments of material aid in scheduling the application of water. Further developments in this field are most certain to come.

THE LYSIMETER FOR MEASURING PERCOLATION

Data on percolation from the lysimeters are presented in two parts: (1) Amounts and rates of percolation, and (2) chemical analysis of the percolates. There is a definite relationship between the two. Variation in the amounts and rates of percolation resulted in variation in the loss of plant nutrients through leaching.

Amounts and Rates

Percolation, the water that moves by gravitational force downward through the soil profile into the underlying sandstone or shale rock, was measured by all 11 lysimeters. This water is no longer available to vegetation. Normally this is the water that contributes to the ground water and thus replenishes the water in springs, wells, and streams.

Most of the percolation through the soil profile occurred during late winter and early spring (tables 26, 27, and 28). During this period soil moisture generally exceeded the field capacity, following several months of almost continuous accretion with little depletion by evapotranspiration (figs. 6–17).

TABLE 26.—*Monthly percolation data, lysimeter battery Y101, 1938–55*

Year and lysimeter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual total
1938:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
A	0.876	1.848	4.548	3.516	0.936	0.708	0.348	0.420	0.060	0	0	0	13.260
B	.804	1.200	2.568	2.244	1.152	1.008	.444	.492	.108	0	.012	Trace	10.032
Average	.840	1.524	3.558	2.880	1.044	.858	.396	.456	.084	0	.006	Trace	11.646
C	.996	2.028	4.764	3.528	1.356	1.044	.444	.456	.180	0	.024	Trace	14.820
1939:													
A	.216	[1]2.204	2.832	3.500	1.060	.706	1.078	.298	.036	.024	.057	.046	12.057
B	.240	[1].942	[1]1.344	[1].366	.904	.628	.994	.271	.022	.239	.030	.057	6.037
Average	.228	1.573	2.088	1.933	.982	.667	1.036	.285	.029	.131	.044	.051	9.047
C	.384	[1]2.462	3.210	[1]2.332	[1].850	.970	1.468	.400	.072	.330	.160	.126	12.764
1940:													
A	.359	.429	1.277	3.572	1.145	2.531	1.210	.426	1.234	.042	.300	1.522	14.047
B	.550	.868	1.462	3.872	1.240	2.334	1.300	.846	.550	.204	.444	1.588	15.258
Average	.455	.648	1.369	3.722	1.193	2.432	1.255	.636	.892	.123	.372	1.555	14.652
C	.726	1.102	2.056	3.842	1.240	2.514	1.324	1.284	.490	.102	.474	1.642	16.796
1941:													
A	1.884	1.368	.828	.672	.636	1.908	2.184	.708	.276	.396	.960	.846	12.666
B	1.536	.299	.678	1.217	.990	1.931	1.951	.660	.102	.114	.034	1.183	10.695
Average	1.710	.834	.753	.944	.813	1.920	2.068	.684	.189	.255	.497	1.015	11.682
C	1.872	.828	1.200	.516	.648	2.112	2.016	.936	.264	.528	.732	.708	12.360

See footnote at end of table.

TABLE 26.—*Monthly percolation data, lysimeter battery Y101, 1938–55*—Continued

Year and lysimeter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual total
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1942:													
A	1. 104	1. 596	2. 838	2. 466	. 918	1. 338	. 912	. 174	. 024	. 018	. 018	1. 560	12. 966
B	. 960	1. 858	3. 024	2. 472	1. 032	1. 266	. 378	. 174	. 036	0	. 078	1. 302	12. 580
Average	1. 032	1. 727	2. 931	2. 469	. 975	1. 302	. 645	. 174	. 030	. 009	. 048	1. 431	12. 773
C	1. 362	1. 314	2. 670	2. 364	1. 080	1. 428	. 888	. 396	. 114	. 048	. 288	1. 188	13. 140
1943:													
A	2. 436	1. 512	3. 024	1. 308	1. 788	2. 364	. 528	. 180	. 048	. 012	. 012	0	13. 212
B	2. 100	1. 464	2. 004	1. 164	1. 416	1. 884	. 492	. 276	. 048	. 012	0	0	10. 860
Average	2. 268	1. 488	2. 514	1. 236	1. 602	2. 124	. 510	. 228	. 048	. 012	. 006	0	12. 036
C	2. 796	1. 428	2. 928	1. 176	1. 824	2. 580	. 600	. 312	. 060	. 012	0	0	13. 716
D	1. 968	1. 440	2. 892	1. 272	1. 668	2. 196	. 612	. 408	. 120	. 024	0	0	12. 600
Average	2. 382	1. 434	2. 910	1. 224	1. 746	2. 388	. 606	. 360	. 090	. 018	0	0	13. 158
1944:													
A	. 012	. 180	3. 900	3. 486	1. 254	. 612	. 276	. 087	. 006	. 012	. 003	. 036	9. 864
B	0	. 180	2. 058	2. 706	1. 122	. 486	. 186	. 018	. 003	. 003	0	. 003	6. 765
Average	. 006	. 180	2. 979	3. 096	1. 188	. 549	. 231	. 052	. 005	. 007	. 002	. 020	8. 315
C	. 024	. 240	4. 068	3. 468	1. 278	. 540	. 198	. 035	. 007	. 004	0	. 023	9. 884
D	. 072	. 108	2. 403	2. 733	1. 044	. 546	. 222	. 012	0	0	0	0	7. 140
Average	. 048	. 174	3. 236	3. 100	1. 161	. 543	. 210	. 024	. 003	. 002	0	. 011	8. 512
1945:													
A	. 750	2. 841	7. 437	2. 471	2. 660	. 976	. 486	. 176	. 886	1. 829	1. 667	2. 076	24. 255
B	. 018	1. 098	4. 516	1. 841	2. 029	. 792	. 357	. 124	. 520	1. 317	1. 313	1. 461	15. 386
Average	. 384	1. 969	5. 977	2. 156	2. 345	. 884	. 421	. 150	. 703	1. 573	1. 490	1. 769	19. 821

C	.357	2.435	7.518	2.487	3.180	1.044	.544	.133	.270	1.191	.826	1.674	21.659
D	0	.636	5.740	1.968	2.441	1.011	.471	.204	.024	.807	.697	1.350	15.349
Average	.179	1.535	6.629	2.228	2.810	1.027	.508	.168	.147	.999	.762	1.512	18.504
1946:													
A	1.698	2.119	2.436	.894	.963	2.649	.930	.384	.192	.090	.591	1.242	14.188
B	1.231	1.532	2.199	.792	.840	2.310	.849	.339	.120	.081	.438	.954	11.685
Average	1.465	1.825	2.318	.843	.902	2.479	.890	.361	.156	.085	.514	1.098	12.936
C	1.156	1.783	2.265	.801	.444	1.510	.864	.198	.042	.012	.099	.648	9.822
D	1.123	1.876	2.106	.801	.423	1.492	.861	.315	.102	.020	.088	.669	9.876
Average	1.140	1.829	2.186	.801	.433	1.501	.862	.256	.072	.016	.094	.658	9.849
1947:													
A	3.562	2.181	1.287	2.313	3.411	2.901	.702	.294	.159	.065	.034	.165	17.074
B	2.517	1.641	.852	1.557	2.487	2.247	.600	.216	.086	.037	.014	.139	12.393
Average	3.040	1.911	1.070	1.935	2.949	2.574	.651	.255	.122	.051	.024	.152	14.734
C	3.282	2.038	1.029	1.635	2.346	2.361	.639	.231	.104	.052	.032	.031	13.780
D	3.258	1.928	1.005	1.653	3.096	2.850	.735	.282	.045	0	0	0	14.852
Average	3.270	1.983	1.017	1.644	2.721	2.606	.687	.256	.074	.026	.016	.016	14.316
1948:													
A	.909	1.125	2.757	4.644	1.830	.765	.390	.204	.070	.008	.126	1.098	13.926
B	.861	1.023	2.160	2.979	1.548	.714	.303	.087	.015	.003	.021	.777	10.491
Average	.885	1.074	2.458	3.812	1.689	.740	.346	.145	.043	.005	.074	.938	12.209
C	.561	1.599	2.709	4.755	1.518	.723	.339	.171	.060	.008	.028	.639	13.110
D	0	.660	1.587	3.264	.083	.007	.004	.008	0	0	0	0	5.613
Average	.280	1.130	2.148	4.009	.801	.365	.171	.090	.030	.004	.014	.320	9.362

TABLE 26.—*Monthly percolation data, lysimeter battery Y101, 1938–55*—Continued

Year and lysimeter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual total
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1949:													
A	3.429	2.682	2.577	2.058	1.161	.498	.963	.693	.243	.225	.075	.471	15.075
B	1.950	1.848	1.890	1.608	1.047	.444	.720	.693	.225	.198	.120	.498	11.241
Average	2.689	2.265	2.234	1.833	1.104	.471	.842	.693	.234	.211	.098	.484	13.158
C	3.651	2.868	2.655	1.884	1.002	.426	1.059	.849	.261	.111	.077	.178	15.021
D	.690	1.149	1.719	1.380	.603	.036	.003	0	0	0	0	0	5.580
Average	2.171	2.009	2.187	1.632	.803	.231	.531	.424	.130	.055	.039	.089	10.301
1950:													
A	6.201	3.525	2.172	2.628	2.118	1.131	.612	.432	1.749	.468	1.287	3.558	25.881
B	3.522	2.568	1.749	2.049	1.653	1.062	.504	.276	1.059	.381	1.080	2.508	18.411
Average	4.862	3.046	1.960	2.338	1.886	1.096	.558	.354	1.404	.424	1.184	3.033	22.145
C	6.876	3.825	2.298	2.814	1.788	1.113	.576	.345	1.620	.375	.888	3.855	26.373
D	1.272	2.460	1.740	1.827	1.062	.471	.027	0	0	0	0	.129	8.988
Average	4.074	3.142	2.019	2.320	1.425	.792	.302	.172	.810	.188	.444	1.992	17.680
1951:													
A	3.753	3.966	3.654	2.832	1.284	.528	.660	.285	.091	.015	.422	2.541	20.031
B	2.685	2.580	2.736	2.475	1.248	.528	.621	.195	.044	.013	.429	1.401	14.955
Average	3.219	3.273	3.195	2.654	1.266	.528	.640	.240	.068	.014	.426	1.971	17.493
C	4.245	3.909	3.783	2.886	1.158	.435	.201	.075	.023	.022	.168	2.499	19.404
D	2.568	3.459	3.417	2.727	1.056	.155	.007	0	0	0	0	0	13.389
Average	3.406	3.684	3.600	2.806	1.107	.295	.104	.038	.012	.011	.084	1.250	16.396

1952:													
A	5. 211	3. 186	2. 475	2. 799	1. 770	1. 068	. 516	. 276	. 099	. 015	. 003	. 243	17. 661
B	3. 081	2. 250	1. 935	2. 136	1. 476	. 993	. 420	. 146	. 034	. 009	. 006	. 027	12. 513
Average	4. 146	2. 718	2. 205	2. 468	1. 623	1. 030	. 468	. 211	. 066	. 012	. 004	. 135	15. 087
C	6. 042	2. 778	2. 658	2. 652	1. 458	. 969	. 720	. 432	. 120	. 034	. 041	. 030	17. 934
D	1. 686	2. 292	2. 028	1. 830	. 867	. 092	. 004	0	0	0	0	0	8. 799
Average	3. 864	2. 535	2. 343	2. 241	1. 162	. 530	. 362	. 216	. 060	. 017	. 020	. 015	13. 365
1953:													
A	2. 526	1. 716	1. 887	1. 824	2. 007	. 933	. 369	. 146	. 010	0	0	. 009	11. 427
B	. 870	1. 233	1. 422	1. 497	1. 623	. 894	. 363	. 165	. 042	. 003	. 002	. 008	8. 122
Average	1. 698	1. 474	1. 654	1. 660	1. 815	. 914	. 366	. 156	. 026	. 002	. 001	. 008	9. 774
C	1. 284	1. 560	1. 959	1. 689	1. 275	. 813	. 516	. 273	. 108	. 022	. 022	. 041	9. 562
D	0	0	. 222	. 741	. 543	. 027	0	0	0	0	0	0	1. 533
Average	. 642	. 780	1. 090	1. 215	. 909	. 420	. 258	. 136	. 054	. 011	. 011	. 020	5. 578
1954:													
A	. 002	. 003	1. 204	1. 618	1. 320	. 594	. 255	. 045	. 003	. 297	. 276	. 537	6. 204
B	. 080	. 243	. 912	1. 341	1. 242	. 579	. 267	. 108	. 030	. 486	. 339	. 609	6. 236
Average	. 041	. 123	1. 058	1. 480	1. 281	. 586	. 261	. 076	. 016	. 392	. 308	. 573	6. 220
C	. 080	. 294	1. 518	2. 007	1. 374	. 702	. 411	. 156	. 036	. 267	. 261	. 333	7. 439
D	0	0	0	0	0	0	0	0	0	0	0	0	0
Average	. 040	. 147	. 759	1. 004	. 687	. 351	. 206	. 078	. 018	. 134	. 130	. 166	3. 720

TABLE 26.—*Monthly percolation data, lysimeter battery Y101, 1938–55*—Continued

Year and lysimeter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual total
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1955:													
A	1. 296	1. 785	3. 993	1. 554	1. 029	. 363	. 135	. 058	. 009	. 002	. 288	. 543	11. 055
B	1. 278	1. 029	2. 115	1. 461	1. 107	. 360	. 147	. 097	. 041	. 026	. 228	. 513	8. 403
Average	1. 287	1. 407	3. 054	1. 508	1. 068	. 362	. 141	. 078	. 025	. 014	. 258	. 528	9. 729
C	1. 173	1. 743	4. 422	1. 608	1. 116	. 345	. 127	. 047	. 026	. 007	. 009	. 156	10. 779
D	0	. 120	1. 050	. 444	. 090	0	0	0	0	0	0	0	1. 764
Average	. 586	. 932	2. 736	1. 026	. 603	. 172	. 064	. 024	. 013	. 004	. 004	. 078	6. 272
Average, 1938–55:													
A (18 years)	2. 012	1. 904	2. 840	2. 453	1. 519	1. 254	. 698	. 294	. 288	. 196	. 340	. 916	14. 714
B (18 years)	1. 349	1. 326	1. 979	1. 877	1. 342	1. 137	. 606	. 288	. 171	. 174	. 255	. 724	11. 228
Average	1. 681	1. 615	2. 410	2. 165	1. 430	1. 196	. 651	. 291	. 230	. 185	. 297	. 820	12. 971
C (18 years)	2. 048	1. 902	2. 984	2. 358	1. 385	1. 202	. 718	. 374	. 214	. 173	. 229	. 765	14. 352
D (13 years)	. 972	1. 241	1. 993	1. 583	. 998	. 684	. 226	. 089	. 023	. 066	. 060	. 165	8. 114

[1] Record incomplete.

TABLE 27.—*Monthly percolation data, lysimeter battery, Y102, 1938–55*

Year and lysimeter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual total
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1938:													
A	1.224	2.268	4.848	3.012	0.408	0.432	0.132	0.024	0	0	0	0	12.348
B	.840	2.232	4.668	2.868	.408	.324	.096	.024	0	0	0	0	11.460
C	[1] .972	2.340	[1] 4.308	2.868	.360	.324	.072	.012	0	0	0	0	[1] 11.256
Average	[2] 1.032	2.280	[2] 4.758	2.916	.392	.360	.100	.020	0	0	0	0	11.858
1939:													
A	0	1.164	1.579	2.288	.387	.150	[1] .061	[1] 0	0	0	0	0	[1] 5.629
B	0	.962	1.706	2.275	.463	.234	.127	[1] 0	0	.043	0	0	[1] 5.810
C	0	.976	1.340	[1] 1.441	.323	.078	.023	.004	0	.009	0	0	[1] 4.194
Average	0	1.034	1.542	[2] 2.282	.391	.154	[2] .070	[2] .004	0	.017	0	0	5.211
1940:													
A	.123	.453	1.779	3.276	.360	.132	.052	.012	0	0	0	0	6.187
B	.044	.130	1.263	3.542	.432	.150	.085	.024	.012	0	0	.091	5.773
C	.020	.128	1.019	2.980	.354	.066	.015	.004	.004	.003	0	0	4.593
Average	.062	.237	1.354	3.266	.382	.116	.051	.013	.005	.001	0	.030	5.517
1941:													
A	.420	.960	.816	.384	.156	.336	.228	.108	.012	0	0	0	3.420
B	.468	.960	.780	.348	.312	.348	.192	.132	0	0	0	0	3.540
C	.119	.114	.064	.042	.187	.156	.090	.051	.002	.004	.031	0	.860
Average	.336	.678	.553	.258	.218	.280	.170	.097	.005	.001	.010	0	2.606
1942:													
A	0	.276	1.818	1.476	.174	.048	.084	.060	.006	.006	0	.204	4.152
B	0	.220	2.012	1.608	.204	.084	.276	.066	.012	.018	0	.150	4.650
C	.006	.222	1.620	1.536	.138	.234	.150	.024	.036	.018	.018	.402	4.404
Average	.002	.239	1.817	1.540	.172	.122	.170	.050	.018	.014	.006	.252	4.402

See footnotes at end of table.

TABLE 27.—*Monthly percolation data, lysimeter battery Y102, 1938–55*—Continued

Year and lysimeter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual total
1943:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
A	1. 608	1. 248	3. 936	1. 092	1. 248	1. 656	. 144	. 060	. 048	. 024	. 024	. 012	11. 100
B	1. 512	1. 392	3. 816	1. 140	1. 272	1. 692	. 084	. 036	0	. 012	0	0	10. 956
C	1. 956	1. 536	3. 636	1. 104	1. 428	1. 668	. 096	. 072	. 024	. 036	. 024	. 012	11. 592
Average	1. 692	1. 392	3. 796	1. 112	1. 316	1. 672	. 108	. 056	. 024	. 024	. 016	. 008	11. 216
1944:													
A	. 012	0	3. 342	3. 150	. 540	. 132	. 030	. 006	0	. 003	0	. 009	7. 224
B	0	0	2. 658	3. 126	. 510	. 114	. 030	. 003	0	0	0	0	6. 441
C	0	. 012	3. 466	3. 222	. 504	. 102	. 024	0	0	0	0	. 021	7. 341
Average	. 004	. 004	3. 155	3. 166	. 518	. 116	. 028	. 003	0	. 001	0	. 010	7. 005
1945:													
A	. 021	. 390	6. 903	1. 275	1. 628	. 372	. 171	. 054	. 014	. 484	. 642	. 921	12. 875
B	0	. 123	6. 939	1. 486	1. 614	. 387	. 159	. 052	. 011	. 081	. 030	. 996	11. 878
C	. 258	2. 215	7. 735	1. 817	1. 827	. 342	. 129	. 036	. 003	. 246	. 675	. 927	16. 210
Average	. 093	. 909	7. 192	1. 526	1. 690	. 367	. 153	. 047	. 009	. 270	. 449	. 948	13. 653
1946:													
A	1. 102	1. 197	. 777	. 141	. 090	. 084	. 126	. 123	. 117	. 165	. 134	. 043	4. 099
B	1. 050	2. 287	1. 445	. 249	. 070	. 019	. 166	. 342	. 051	. 013	. 002	0	5. 694
C	1. 083	2. 456	1. 659	. 242	. 080	. 071	. 105	. 125	. 019	. 027	. 044	. 151	6. 062
Average	1. 078	1. 980	1. 294	. 211	. 080	. 058	. 132	. 197	. 062	. 068	. 060	. 065	5. 285
1947:													
A	1. 635	. 649	. 168	1. 167	1. 485	. 588	. 054	. 044	. 038	. 036	. 029	. 018	5. 911
B	2. 717	1. 054	. 363	2. 067	1. 845	. 777	. 068	. 039	. 023	. 018	. 015	. 012	8. 998
C	4. 096	1. 163	. 423	2. 007	3. 000	1. 457	. 076	. 016	. 004	. 003	. 011	. 004	12. 260
Average	2. 816	. 955	. 318	1. 747	2. 110	. 941	. 066	. 033	. 022	. 019	. 018	. 011	9. 086

1948:													
A	.021	.016	.158	2.079	.038	.031	.035	.025	.025	.019	.019	.016	2.482
B	.007	.016	.847	3.969	.098	.022	.016	.011	.007	.005	.009	.006	5.013
C	.010	.143	2.331	3.884	.104	.004	.006	.003	0	.011	.013	.012	6.521
Average	.013	.058	1.112	3.311	.080	.019	.019	.013	.011	.012	.014	.011	4.672
1949:													
A	.081	.790	1.182	.551	.271	.186	.104	.033	.002	.002	.009	0	3.212
B	0	.344	2.016	1.001	.336	.315	.129	.044	.018	.013	.007	.006	4.229
C	.138	1.347	2.018	.939	.462	.318	.177	.057	.003	.005	.016	0	5.480
Average	.073	.827	1.739	.830	.356	.273	.137	.045	.008	.007	.011	.002	4.307
1950:													
A	3.531	3.099	1.794	1.908	.588	.105	.030	.009	.696	.039	.042	1.962	13.803
B	4.497	3.012	1.815	1.983	.612	.120	.046	.191	1.284	.108	.093	2.757	16.518
C	4.842	3.258	1.848	2.025	.621	.112	.041	.201	1.749	.072	.063	2.934	17.766
Average	4.290	3.123	1.819	1.972	.607	.112	.039	.134	1.243	.073	.066	2.551	16.029
1951:													
A	4.137	3.606	3.498	2.424	.573	.102	.063	.025	.012	.006	.004	.037	14.487
B	4.173	3.606	3.651	2.472	.546	.117	.090	.060	.053	.038	.034	.028	14.868
C	4.098	4.086	3.630	2.535	.510	.061	.005	.003	0	.005	.009	.151	15.093
Average	4.136	3.766	3.593	2.477	.543	.093	.053	.029	.022	.016	.016	.072	14.816
1952:													
A	2.583	1.521	1.335	.963	.101	.025	.054	.057	.057	.043	.023	.015	6.777
B	3.087	2.592	2.217	1.779	.275	.049	.032	.035	.029	.026	.020	.014	10.155
C	4.131	2.721	2.505	1.932	.368	.023	.002	.003	0	.003	0	0	11.688
Average	3.267	2.278	2.019	1.558	.248	.032	.029	.032	.029	.024	.014	.010	9.540

TABLE 27.—*Monthly percolation data, lysimeter battery Y102, 1938–55*—Continued

Year and lysimeter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual total
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1953:													
A	.017	.006	.016	.016	.044	.054	.057	.055	.050	.039	.023	.019	.396
B	.013	.004	.019	.063	.474	.147	.054	.062	.041	.035	.026	.025	.963
C	.003	.003	.165	.513	1.236	.429	.393	.222	.048	.009	.003	.003	3.027
Average	.011	.004	.067	.197	.585	.210	.168	.113	.046	.028	.017	.016	1.462
Average [3]	.008	.004	.092	.288	.855	.288	.224	.142	.044	.022	.014	.014	1.995
1954:													
A	.029	.014	.017	.025	.021	.023	.034	.029	.021	.024	.018	.069	.324
B	.019	.018	.320	.501	.071	.028	.036	.033	.024	.031	.020	.123	1.224
C	.051	.066	1.797	1.104	.165	.033	.003	.006	0	0	0	.006	3.231
Average	.033	.033	.711	.543	.086	.028	.024	.023	.015	.018	.013	.066	1.593
Average [4]	.035	.042	1.058	.802	.118	.030	.020	.020	.012	.016	.010	.064	2.227
1955:													
A	.077	1.672	3.672	.576	.180	.021	.003	0	.003	0	0	0	6.204
B	.087	2.039	3.235	.777	.339	.177	.129	.042	.009	.008	.001	0	6.843
C	.117	2.292	4.017	.918	.315	.031	.008	0	0	.005	.007	.006	7.716
Average	.094	2.001	3.641	.757	.278	.076	.047	.014	.004	.004	.003	.002	6.921
Average [5]	.102	2.166	3.626	.848	.327	.104	.068	.02	.004	.006	.004	.003	7.280
18-year average:													
A	.924	1.074	2.093	1.434	.461	.248	.081	.040	.061	.050	.053	.185	6.704
B	1.028	1.166	2.209	1.736	.549	.283	.101	.066	.087	.025	.014	.234	7.498
C	1.217	1.393	2.419	1.728	.666	.306	.078	.047	.105	.025	.051	.257	8.292
Average	1.056	1.211	2.240	1.633	.559	.279	.087	.051	.084	.033	.039	.225	7.498

[1] Record incomplete.
[2] Average includes complete records only.
[3] Average of B and C; irrigated on July 14, Aug. 25, Oct. 12 and 21, 1953—total, 7.79 inches.
[4] Average of B and C; irrigated on July 16 and Sept. 13, 1954—total, 2.74 inches.
[5] Average of B and C; irrigated on May 18 and June 29, 1955—total, 5.26 inches.

TABLE 28.—*Monthly percolation data, lysimeter battery Y103, 1940–55*

Year and lysimeter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual total
1940:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
A	------	------	(1)	(1)	(1)	0.067	0.024	0.124	0.018	0.018	0.030	0.732	[1] 1.013
B	------	------	[1] 0.304	1.925	0.063	.042	.077	.185	.018	.006	.132	.984	[1] 3.736
Average	------	------	[1] .152	[1] .962	[1] .032	.055	.050	.155	.018	.012	.081	.858	[1] 2.375
C	------	------	[1] .094	1.797	.053	.018	.030	.035	.011	.006	.012	.816	[1] 2.872
D	------	------	[1] .136	1.328	.054	.042	.136	.180	.018	.006	.024	.744	[1] 2.668
Average	------	------	[1] .115	1.562	.054	.030	.083	.107	.015	.006	.018	.780	[1] 2.770
1941:													
A	.624	.306	.186	.052	.042	.042	.018	.024	.054	.036	.054	.096	1.533
B	.708	.672	.672	.144	.072	.312	.024	.048	0	0	.048	.120	2.820
Average	.666	.489	.429	.098	.057	.177	.021	.036	.027	.018	.051	.108	2.177
C	.720	.876	.720	.192	.036	.360	.048	.048	.036	0	.060	.228	3.324
D	.576	.732	.348	.228	.048	.132	.024	.144	.108	.036	.036	.192	2.604
Average	.648	.804	.534	.210	.042	.246	.036	.096	.072	.018	.048	.210	2.964
1942:													
A	.138	.900	1.962	.948	.042	.246	.090	.018	.018	.006	.162	1.992	6.522
B	.108	.870	1.608	.804	.042	.156	.126	.018	.012	.012	.048	.612	4.416
Average	.123	.885	1.785	.876	.042	.201	.108	.018	.015	.009	.105	1.302	5.469
C	.234	1.050	2.094	1.080	.054	.360	.102	.030	.024	.006	.048	1.926	7.008
D	.162	.978	.912	.252	.102	.090	.036	.024	.012	.024	.024	2.046	4.662
Average	.198	1.014	1.503	.666	.078	.225	.069	.027	.018	.015	.036	1.986	5.835

See footnote at end of table.

TABLE 28.—*Monthly percolation data, lysimeter battery Y103, 1940–55*—Continued

Year and lysimeter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual total
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1943:													
A	1. 176	1. 212	2. 316	. 660	1. 908	. 528	. 048	. 060	. 024	. 024	. 012	0	7. 968
B	. 948	. 600	. 720	. 996	1. 800	. 564	. 036	. 024	0	0	. 024	. 012	5. 724
Average	1. 062	. 906	1. 518	. 828	1. 854	. 546	. 042	. 042	. 012	. 012	. 018	. 006	6. 846
C	1. 188	1. 512	2. 868	. 792	1. 836	. 756	. 048	. 024	. 024	. 012	0	. 024	9. 084
D	1. 056	. 636	. 672	. 312	. 636	. 240	. 036	. 024	. 024	0	. 012	. 036	3. 684
Average	1. 122	1. 074	1. 770	. 552	1. 236	. 498	. 042	. 024	. 024	. 006	. 006	. 030	6. 384
1944:													
A	. 036	. 252	2. 934	1. 674	. 072	. 036	. 024	. 015	. 012	. 003	0	0	5. 058
B	. 048	. 072	2. 436	2. 088	. 048	. 012	. 015	. 015	0	0	0	. 018	4. 752
Average	. 042	. 162	2. 685	1. 881	. 060	. 024	. 020	. 015	. 006	. 002	0	. 009	4. 905
C	. 036	. 036	3. 042	2. 142	. 108	. 036	. 033	. 021	. 009	. 009	. 006	. 014	5. 492
D	. 036	. 024	2. 226	1. 716	. 078	. 030	. 012	. 009	. 003	. 006	0	. 005	4. 145
Average	. 036	. 030	2. 634	1. 929	. 093	. 033	. 023	. 015	. 006	. 008	. 003	. 009	4. 819
1945:													
A	0	1. 371	5. 468	1. 368	. 780	. 060	. 028	. 014	. 546	. 431	. 765	. 183	11. 014
B	. 014	1. 387	3. 220	. 693	. 363	. 087	. 020	. 007	. 309	. 153	. 163	. 105	6. 521
Average	. 007	1. 379	4. 344	1. 031	. 571	. 073	. 024	. 010	. 428	. 292	. 464	. 144	8. 767
C	. 019	1. 842	4. 956	1. 848	1. 066	. 096	. 052	. 029	. 881	. 864	1. 141	. 372	13. 166
D	. 004	. 876	4. 746	. 957	. 471	. 022	. 015	. 005	. 840	. 330	. 381	. 216	8. 863
Average	. 011	1. 359	4. 851	1. 402	. 769	. 059	. 034	. 017	. 860	. 597	. 761	. 294	11. 014

1946:													
A	.797	2.195	1.034	.062	.029	.497	.040	.017	.013	.011	.006	.280	4.981
B	.097	.095	.273	.062	.028	.080	.065	.020	0	.021	.035	.304	1.080
Average	.447	1.145	.654	.062	.028	.289	.053	.018	.006	.016	.020	.292	3.030
C	1.019	.984	1.386	.068	.041	.470	.084	.034	.020	.016	.019	.574	4.715
D	.293	.241	.484	.055	.029	.566	.047	.018	.013	.007	.010	.457	2.220
Average	.656	.612	.935	.062	.035	.518	.066	.026	.017	.011	.014	.516	3.468
1947:													
A	3.319	.282	.576	1.896	2.658	1.114	.045	.032	.016	.010	.005	.003	9.956
B	1.578	.432	.327	1.962	1.793	.786	.040	.028	.019	.004	.032	.038	7.039
Average	2.448	.357	.452	1.929	2.225	.950	.042	.030	.018	.007	.018	.020	8.496
C	2.809	.507	.681	2.199	2.871	1.374	.053	.030	.022	.012	.014	.013	10.585
D	1.620	.372	.411	1.479	2.139	.744	.050	.030	.019	.009	.012	.006	6.891
Average	2.214	.440	.546	1.839	2.505	1.059	.052	.030	.020	.010	.013	.010	8.738
1948:													
A	.007	1.544	2.188	2.420	.101	.022	.012	.009	0	.003	0	.003	6.309
B	.029	1.544	1.935	1.005	.203	.052	.038	.004	.030	.026	.058	.043	4.967
Average	.018	1.544	2.062	1.713	.152	.037	.025	.006	.015	.014	.029	.023	5.638
C	.240	2.400	2.487	2.695	.608	.045	.033	.018	.009	0	.003	.246	8.784
D	.073	2.219	2.064	2.049	.367	.032	.029	.010	.040	.026	.012	.150	7.071
Average	.157	2.310	2.276	2.372	.487	.038	.031	.014	.025	.013	.007	.198	7.928
1949:													
A	1.959	1.585	1.422	.366	.138	.012	.053	.001	.003	.003	0	0	5.542
B	2.569	1.920	1.563	.624	.180	.022	.088	.010	.033	.006	.012	.033	7.060
Average	2.264	1.753	1.493	.495	.159	.017	.070	.005	.018	.004	.006	.017	6.301
C	2.499	1.839	1.848	.813	.441	.084	.483	.057	.022	.013	.013	.087	8.199
D	2.787	1.864	1.665	.558	.360	.055	.133	.031	.022	.005	.006	.108	7.594
Average	2.643	1.852	1.757	.685	.401	.069	.308	.044	.022	.009	.009	.098	7.897

TABLE 28.—*Monthly percolation data, lysimeter battery Y103, 1940–55*—Continued

Year and lysimeter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual total
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1950:													
A	4. 755	2. 208	1. 254	1. 626	. 127	. 035	. 019	. 016	. 043	. 015	. 093	2. 670	12. 861
B	5. 037	2. 121	1. 188	1. 686	. 330	. 057	. 082	. 044	. 102	. 021	. 129	1. 557	12. 354
Average	4. 896	2. 164	1. 221	1. 656	. 228	. 046	. 050	. 030	. 072	. 018	. 111	2. 113	12. 605
C	5. 304	2. 322	1. 518	1. 602	. 495	. 096	. 041	. 043	. 092	. 019	. 225	1. 734	13. 491
D	5. 169	2. 175	1. 302	1. 188	. 660	. 099	. 051	. 036	. 337	. 014	. 114	2. 154	13. 299
Average	5. 236	2. 248	1. 410	1. 395	. 578	. 098	. 046	. 040	. 214	. 016	. 170	1. 944	13. 395
1951:													
A	3. 618	3. 468	3. 303	1. 908	. 171	. 056	. 028	. 022	. 012	. 006	. 010	1. 090	13. 692
B	1. 755	. 885	1. 293	1. 074	. 240	. 070	. 047	. 021	. 062	. 014	. 084	1. 190	6. 735
Average	2. 686	2. 176	2. 298	1. 491	. 206	. 063	. 038	. 022	. 037	. 010	. 047	1. 140	10. 214
C	2. 604	1. 503	3. 171	1. 980	. 156	. 050	. 037	. 020	. 015	. 004	. 039	1. 683	11. 262
D	3. 168	1. 581	3. 078	1. 629	. 159	. 047	. 031	. 017	. 030	. 010	. 050	2. 233	12. 033
Average	2. 886	1. 542	3. 124	1. 804	. 158	. 048	. 034	. 018	. 022	. 007	. 044	1. 958	11. 648
1952:													
A	3. 648	1. 863	1. 920	1. 581	. 067	. 023	. 015	. 011	. 004	0	. 004	. 005	9. 141
B	3. 117	1. 245	1. 650	1. 650	. 138	. 060	. 073	. 040	. 058	. 006	. 027	. 096	8. 160
Average	3. 382	1. 554	1. 785	1. 616	. 102	. 042	. 044	. 026	. 031	. 003	. 016	. 050	8. 650
C	3. 183	1. 494	1. 626	1. 680	. 113	. 046	. 030	. 016	. 005	0	0	. 012	8. 250
D	3. 462	1. 431	1. 557	1. 752	. 252	. 077	. 035	. 013	. 007	. 003	. 012	. 018	8. 619
Average	3. 322	1. 462	1. 592	1. 716	. 182	. 062	. 032	. 014	. 006	. 002	. 006	. 015	8. 434

1953:													
A	.183	.342	.981	.504	.417	.024	.010	.009	.002	.008	.009	.016	2.505
B	.696	.690	1.434	.840	.666	.063	.052	.018	.011	.003	.005	.097	4.575
Average	.440	.516	1.208	.672	.542	.044	.031	.014	.006	.006	.007	.056	3.543
C	1.062	.852	1.359	.865	.915	.090	.038	.021	.013	.009	.005	.022	5.251
D	.855	.645	1.362	.888	.810	.078	.086	.024	.008	.007	.001	.087	4.851
Average	.958	.748	1.360	.876	.862	.084	.062	.022	.010	.008	.003	.054	5.052
1954:													
A	.036	.009	.240	.255	.049	.012	.013	.010	0	.003	.003	.009	.639
B	.206	.085	.732	.684	.221	.046	.063	.063	.013	.143	.033	.147	2.436
Average	.121	.047	.486	.470	.135	.029	.038	.036	.006	.073	.018	.078	1.538
C	.342	.021	1.320	.408	.288	.051	.030	.018	.012	.042	.009	.426	2.967
D	.426	.063	1.602	.441	.333	.033	.046	.053	.006	.221	.037	.576	3.837
Average	.384	.042	1.461	.424	.310	.042	.038	.036	.009	.132	.023	.501	3.402
1955:													
A	.085	1.934	2.676	.354	.111	.031	.024	.014	.009	.005	.024	.015	5.283
B	.180	2.241	2.988	.297	.081	.039	.063	.066	.018	.026	.076	.009	6.084
Average	.132	2.088	2.832	.326	.096	.035	.044	.040	.014	.016	.050	.012	5.684
C	.598	2.894	2.448	.678	.114	.036	.037	.020	.011	.009	.031	.006	6.882
D	.549	3.978	2.922	750	.084	.013	.018	.032	.007	.013	.037	.015	8.418
Average	.574	3.436	2.685	.714	.099	.024	.028	.026	.009	.011	.034	.010	7.650
Average, 1941–55:													
A	1.359	1.298	1.897	1.045	.447	.183	.031	.018	.050	.038	.077	.426	6.883
B	1.139	.991	1.469	.974	.414	.160	.055	.028	.044	.022	.052	.292	5.640
Average	1.249	1.144	1.683	1.010	.430	.172	.043	.023	.047	.030	.064	.359	6.262
C	1.457	1.341	2.102	1.269	.609	.263	.077	.028	.079	.067	.107	.491	7.890
D	1.349	1.188	1.690	.950	.435	.151	.043	.031	.098	.047	.050	.553	6.585
Average	1.403	1.264	1.896	1.110	.522	.207	.060	.030	.088	.057	.078	.522	7.237

[1] Record incomplete.

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For the period 1938–55 approximately 80 percent of the percolation occurred during the first 4 months of the year on battery Y102 (table 27) and 65 percent on battery Y101 (table 26). For the period 1941–55 on battery Y103, 81 percent occurred on the conservation-practice lysimeters during the same 4-month period and 78 percent occurred on poor-practice lysimeters (table 28). During the late spring and summer months, when evapotranspiration rates were high, soil moisture was reduced to such an extent that there was generally little water in the profile available for percolation.

Soil moisture generally reached its lowest level of the year sometime between August and October near the end of the period of high rate of water use by crops (high ET—CA value). From October until spring, accretion usually exceeded depletion; there was very little ET—CA. High rates of percolation paralleled high soil-moisture content of the soil profile.

Monthly and annual values of percolation from all lysimeters are given in tables 26, 27, and 28. Curves of accumulated monthly percolation by years for the period 1938–55 appear in figures 38, 39, 40, and 41. Precipitation, especially during the winter and spring months, directly affects percolation. As soil type, soil moisture, land use, and freezing affect the amount of water absorbed by the soil, they also affect the amount of water available for percolation. A reduction in either surface runoff or evapotranspiration tends to increase percolation.

During corn years and to a lesser extent during wheat years, surface runoff generally is higher and infiltration is lower than during meadow years. Consequently, a lesser amount of moisture is available for percolation in the soil profile during corn years. However, percolation was lower during some dry years from the meadow lysimeters than during a wet year from the corn lysimeters. For example, 45.45 inches of rainfall produced 12.88 inches of percolation on lysimeter Y102A when it was in corn in 1945. In 1955, when the same lysimeter was in meadow, 30.69 inches of rainfall produced only 6.20 inches of percolation.

In some such instances, it is desirable to express percolation as a percentage of infiltration (precipitation minus runoff). Previous data from this station (*37*) have shown that percolation, expressed as a percentage of infiltration, is highest during meadow years and lowest during corn years.

The greatest amount of percolation was obtained from the Muskingum silt loam of sandstone origin (battery Y101). Maximum percolation for 1 year was 26.37 inches obtained from Y101C in 1950. Annual precipitation that year was over 47 inches. Minimum annual percolation was zero from Y101D in 1954. Factors causing this minimum percolation were: (1) Rainfall in 1954 was about 10 inches below normal, (2) rainfall in 1953 was also deficient by the same amount, and (3) this lysimeter (Y101D), unlike any others, was in an alfalfa-bromegrass cover in 1953 and 1954. Apparently this vegetative cover, by means of its long roots, removed soil moisture to such an extent that moisture recharge in the profile in 1954 was not enough to provide free or gravitational water at the bottom of the 8-foot profile.

The vegetation on all lysimeters of battery Y101 was the same (poverty grass) through 1944 except that Y101D was bare in 1943, its first year of operation. Percolation values for Y101D appear to correspond closely with those for Y101B from 1944 through 1946 (figs. 39 and 40). Y101C and Y101D were seeded to bluegrass and clover in

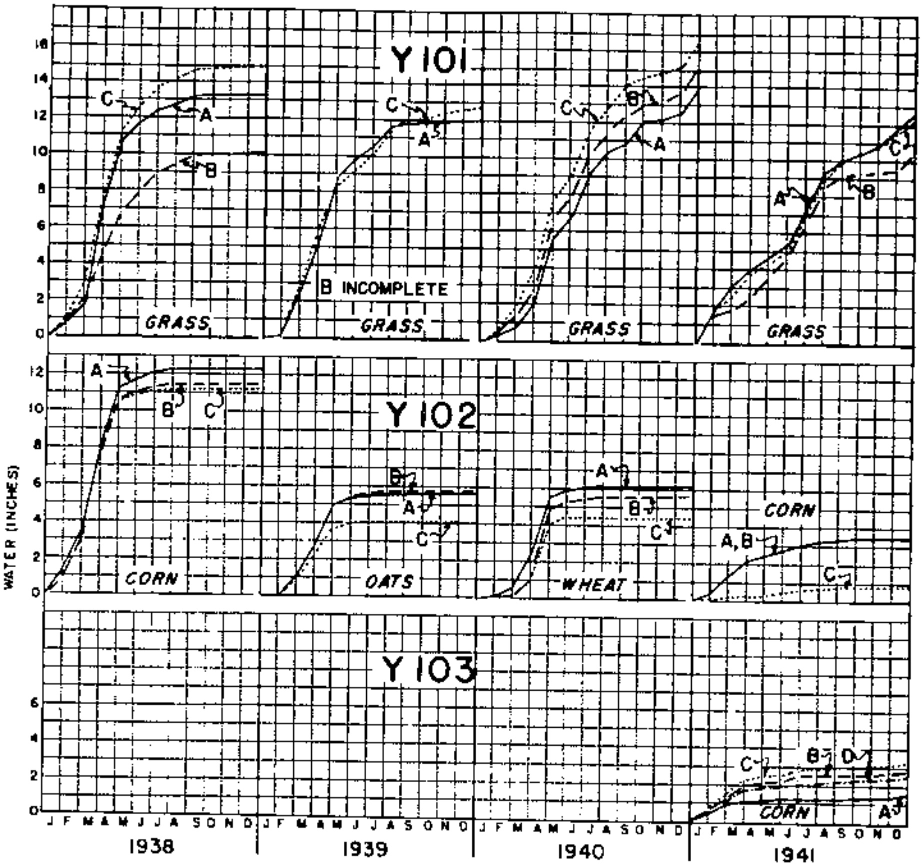

FIGURE 38.—Accumulated monthly percolation by years, 1938–41.

1946, whereas Y101A and Y101B remained in poverty grass. In 1947 percolation was greater from Y101D than from Y101C. This was the year the old sod was destroyed and lysimeter Y101D was seeded to alfalfa and bromegrass. ET—CA was low. More water was available for percolation. For the period 1948–55 (figs. 40 and 41), however, the reverse was true—percolation from Y101D was low. This was largely because of the increased transpiration from alfalfa and bromegrass on Y101D. As ET increased, a lesser amount of water was available for percolation.

Percolation values along with vegetal changes for lysimeters Y101B, Y101C, and Y101D for the period 1944–55 are shown in table 29. Data from Y101A are omitted because of soil slumping during construction operations.

Evapotranspiration values for Y-101D for the period 1944–47 (April–August) are low. Poverty grass was the predominant cover on all three lysimeters during this period.

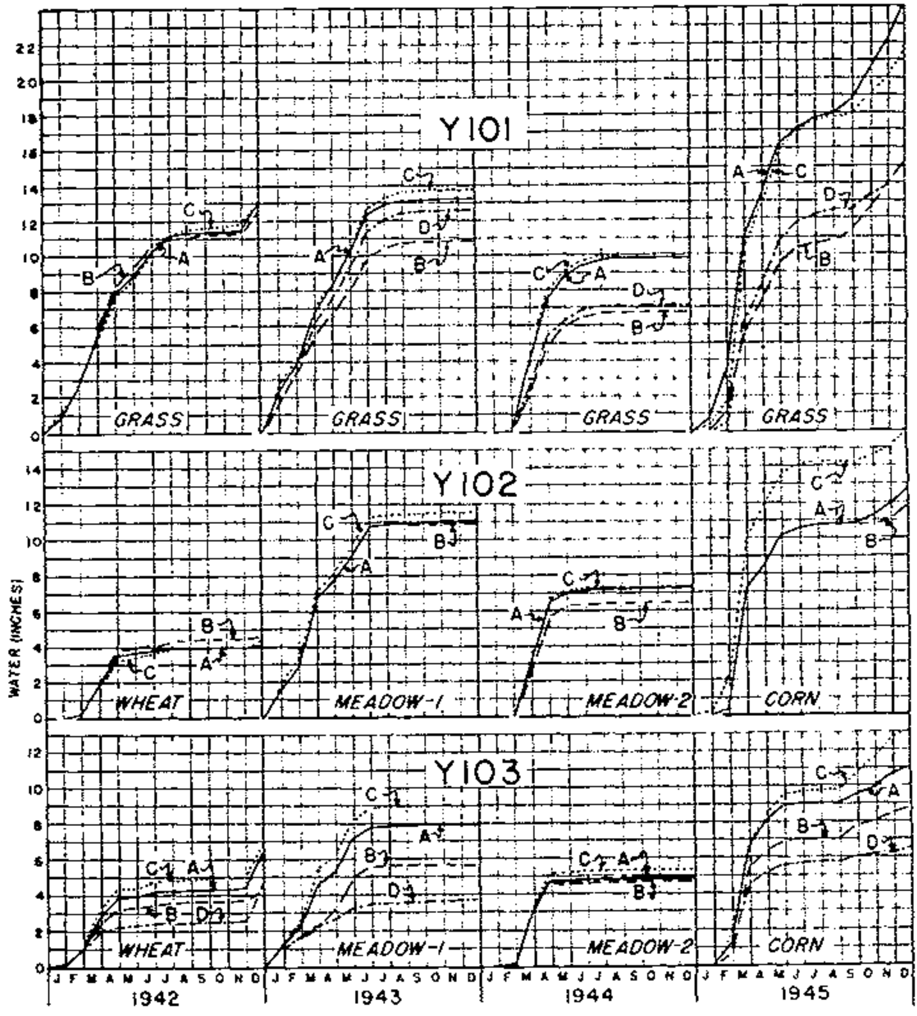

FIGURE 39.—Accumulated monthly percolation by years, 1942–45.

ET for the period 1948–55, after the alfalfa-bromegrass cover had become established, was considerably higher than before. The annual average ET—CA value for the alfalfa-bromegrass period was 24.9 inches as compared with 20.2 inches for the previous period. The contrast in annual percolation values for the lysimeters in battery Y101 emphasizes the influence of vegetation on soil-water relationships. Although there may be several reasons why percolation from lysimeter Y101D was much less for the period 1948–55, it appears that evapotranspiration was by far the most influential factor.

Although the soil is classified as Muskingum silt loam on both lysimeter batteries Y101 and Y102, the sandstone bedrock in battery Y101 has produced a very permeable soil through which soil water percolates freely. Shale on Y102 has produced a heavier soil with lower permeability and therefore lower percolation values. Maximum annual percolation from battery Y102 was 17.77 inches from Y102C in 1950. The minimum was 0.32 inch from Y102A in 1954.

The highest monthly percolation from the lysimeters in battery Y102 was 7.73 inches obtained from Y102C in March 1945. There were a number of years when there was no percolate in September, October, November, December, or January. Percolation was appreciably lower from battery Y102 than from battery Y101. The effect of soil type on percolation is evident from a comparison of percolation from the

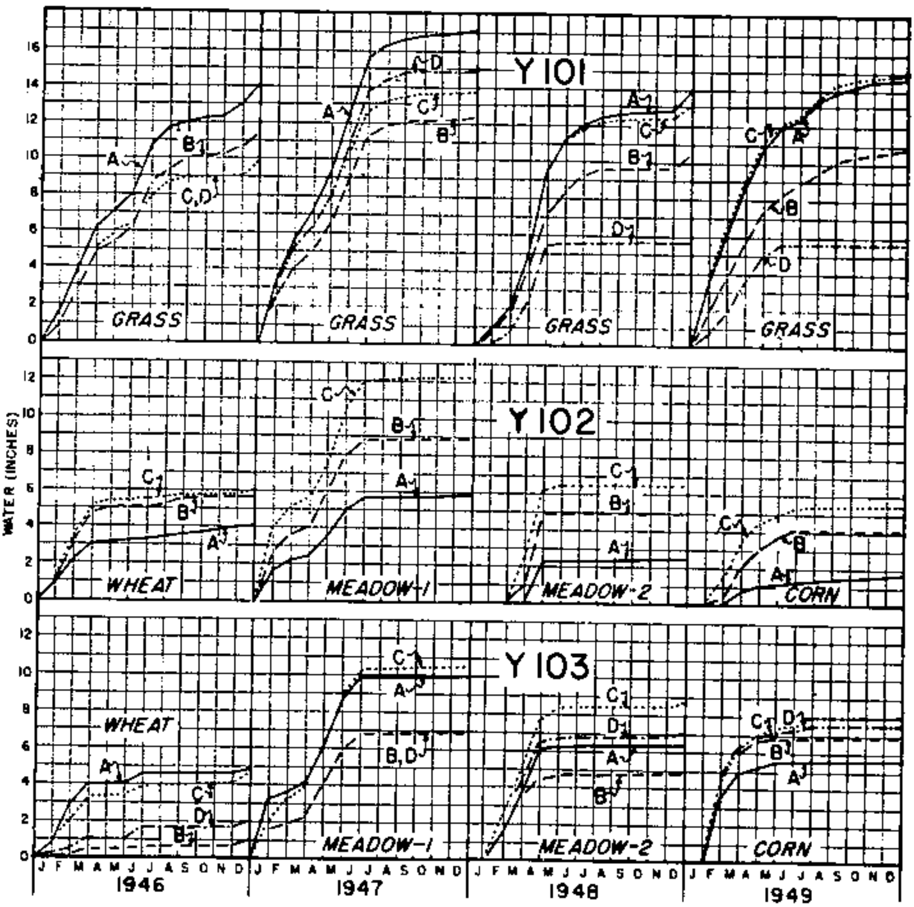

FIGURE 40.—Accumulated monthly percolation by years, 1946–49.

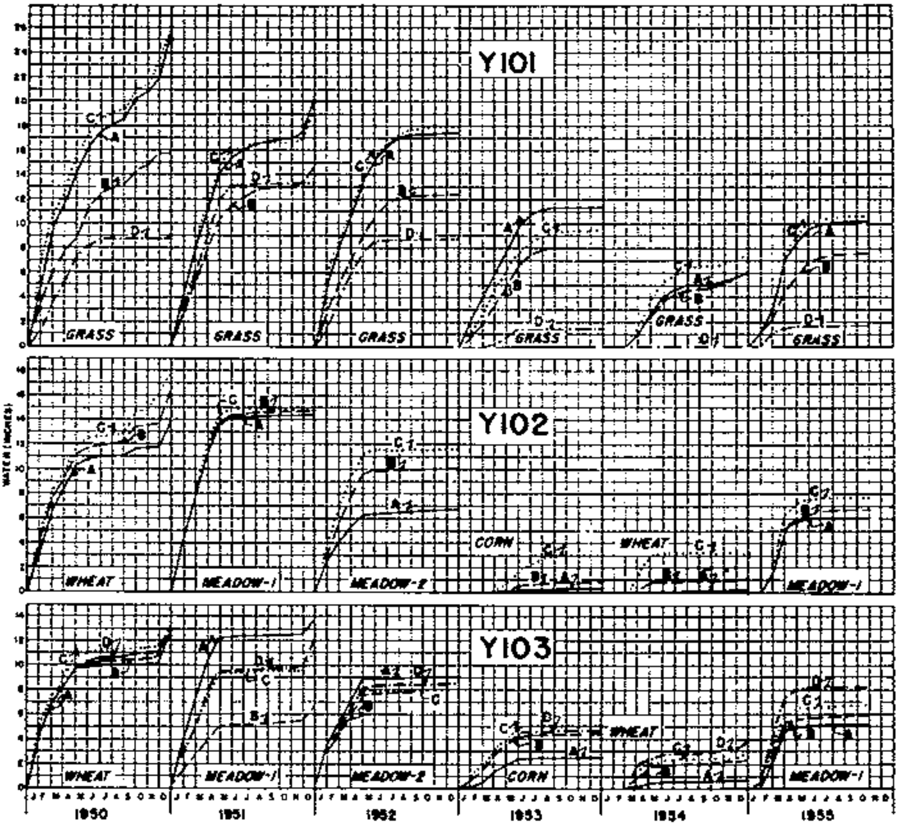

FIGURE 41.—Accumulated monthly percolation by years, 1950–55.

TABLE 29.—*Percolation, evapotranspiration, and vegetative cover for lysimeters Y101B, Y101C, and Y101D, 1944–55*

Year and lysimeter	Cover	Annual percolation	Evapotranspiration (ET−CA), Apr.–Aug.
		Inches	*Inches*
1944:			
Y101B	Poverty grass	6. 8	
Y101C	do	9. 9	
Y101D	do	7. 1	18. 4
1945:			
Y101B	Poverty grass	15. 4	
Y101C	New seeding of bluegrass and clover	21. 7	
Y101D	do	15. 3	18. 4
1946:			
Y101B	Poverty grass	11. 7	
Y101C	Bluegrass and clover	9. 8	
Y101D	do	9. 9	23. 7

TABLE 29.—*Percolation, evapotranspiration, and vegetative cover for lysimeters Y101B, Y101C, and Y101D, 1944–55*—Continued

Year and lysimeter	Cover	Annual percolation	Evapotranspiration (ET—CA), Apr.–Aug.
		Inches	*Inches*
1947:			
Y101B	Poverty grass	12.4	
Y101C	Bluegrass	13.8	
Y101D	New seeding of bromegrass, ladino clover, and alfalfa.	14.9	20.2
1948:			
Y101B	Poverty grass	10.5	
Y101C	Bluegrass	13.1	
Y101D	Bromegrass, ladino clover, and alfalfa	5.6	23.2
1949:			
Y101B	Poverty grass	11.2	
Y101C	Bluegrass	15.0	
Y101D	Bromegrass and alfalfa	5.6	27.0
1950:			
Y101B	Poverty grass	18.4	
Y101C	Bluegrass	26.4	
Y101D	Bromegrass and alfalfa	9.0	25.5
1951:			
Y101B	Poverty grass	15.0	
Y101C	Bluegrass	19.4	
Y101D	Bromegrass and alfalfa	13.4	24.2
1952:			
Y101B	Poverty grass	12.5	
Y101C	Bluegrass	17.9	
Y101D	Bromegrass and alfalfa	8.8	27.0
1953:			
Y101B	Poverty grass	8.1	
Y101C	Bluegrass	9.6	
Y101D	Bromegrass and alfalfa	1.5	23.4
1954:			
Y101B	Poverty grass	6.2	
Y101C	Bluegrass	7.4	
Y101D	Bromegrass and alfalfa	0	22.7
1955:			
Y101B	Poverty grass	8.4	
Y101C	Bluegrass	10.8	
Y101D	Bromegrass and alfalfa	1.7	26.1
Average:			
1944–47:			
Y101B	Poverty grass	11.6	
Y101C	Bluegrass	13.8	
Y101D	do	11.8	20.2
1948–55:			
Y101B	Poverty grass	11.3	
Y101C	Bluegrass	15.0	
Y101D	Bromegrass and alfalfa	5.7	24.9

Keene silt loam (battery Y103) with that for Muskingum silt loam (battery Y102). Percolation rates were more erratic on the Keene because of the texture and structure of the various soil horizons. The subsoil of the Keene is a heavy silt loam grading into silty clay loam and then into silty clay. The high colloidal content of the latter enhances swelling and shrinking of this soil layer, which directly affects percolation. When the soil is saturated or nearly so, the colloids swell to such an extent that the soil is almost impermeable. The soil shrinks when it dries, and the cracks that are produced facilitate percolation of the soil water. Presumably, these cracks close very slowly because high percolation rates sometimes occur many times over a period of several months. The highest monthly percolation on the Keene silt loam was 5.47 inches from lysimeter Y103A in March 1945. The highest annual percolation on this soil was 13.49 inches in 1950; the lowest was 0.64 inch in 1954.

The difference in the amount of percolation from heavy rainfall in March and September 1945 was extremely great, as shown in figure 42. Rain in March totaled 7.5 inches; and percolation averaged 6.3 inches for the lysimeters in battery Y101, 7.2 inches for Y102, and 4.6 inches for Y103. Rain in September totaled 9.5 inches; and percolation averaged 0.4 inch for Y101, 0.3 inch for Y102, and 0.6 inch for Y103 (fig. 43).

The difference in soil moisture—very wet in March and very dry prior to the September rain—was

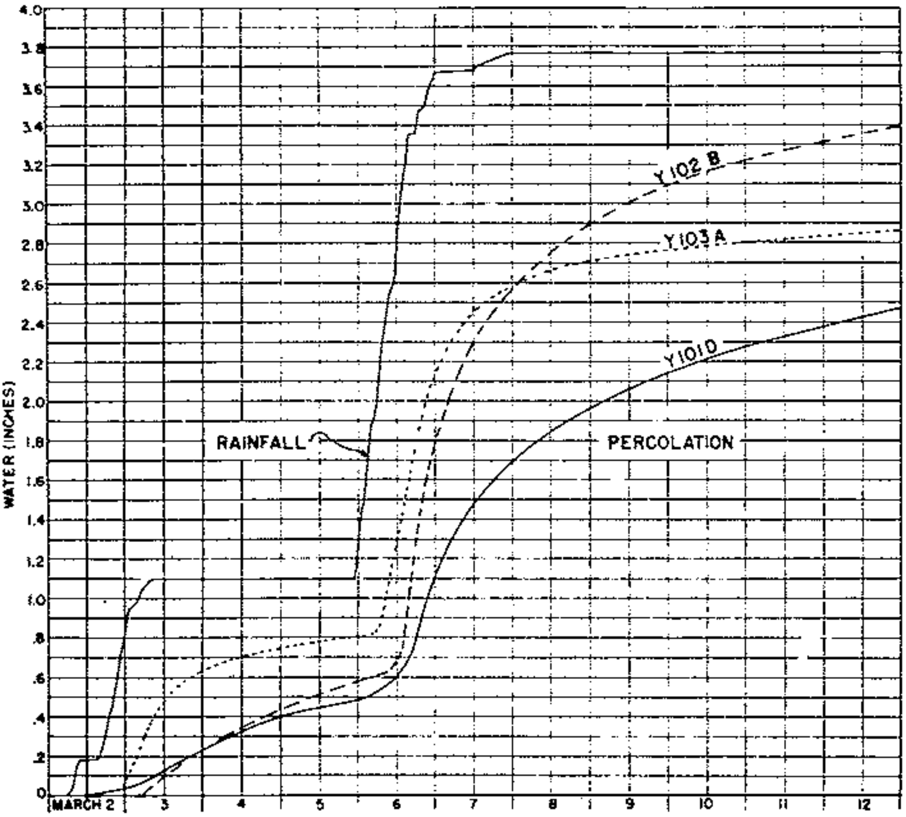

FIGURE 42.—Typical curves of accumulated percolation following rainfall on wet soil, March 2, 1945.

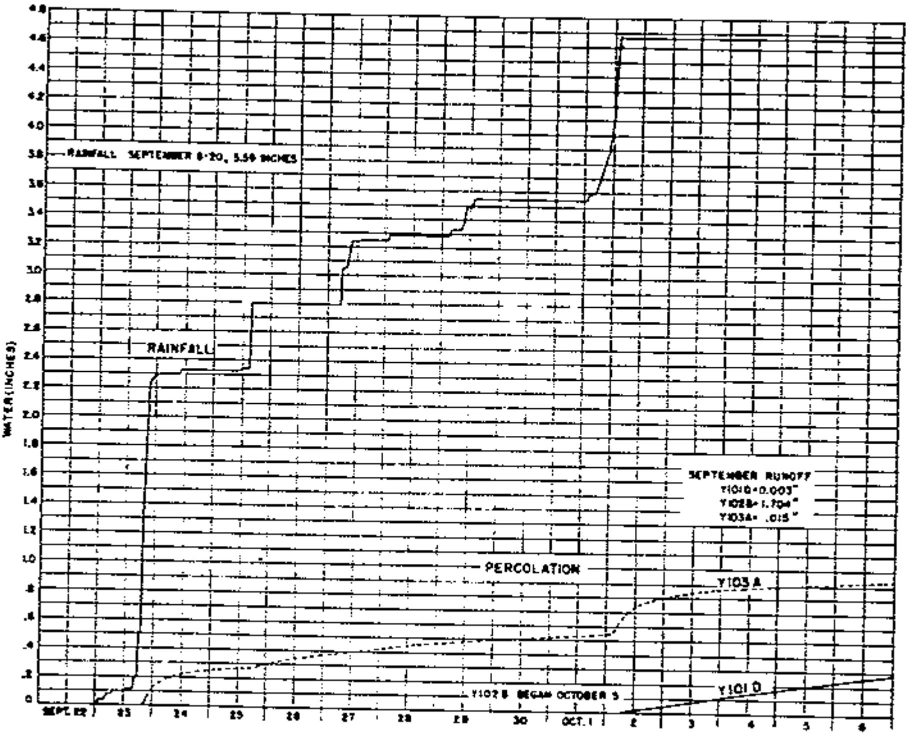

FIGURE 43.—Typical curves of accumulated percolation following a dry summer period, September 22–October 6, 1945.

a major reason for the difference in percolation for the two periods.

A detailed study of periods of high rainfall and percolation rates (figs. 42 and 43) shows the approximate timelag of percolation after rainfall. Typical curves for each of the three batteries of lysimeters were selected for comparison. In figure 42, percolation is compared with rainfall for the period March 2–12, 1945. Soil moisture preceding this period was well above field capacity. Percolation was active in all lysimeters immediately prior to March 2. Percolation increased markedly after both the March 2 and March 6 storms. After a definite increase in rainfall on March 6, percolation began to respond in about 8 hours from Y103A, in 12 hours from Y102B, and in about 16 hours from Y101D. This does not mean that the rain falling on the ground appeared at the 8-foot level of the soil in the lysimeters 8, 12, or 16 hours later; it means that the rainfall was effective in causing an increase in the amount of water seeping from the bottom of the lysimeters 8, 12, or 16 hours after the rain began.

The maximum rate of percolation for a 3-hour period ranged between 0.07 and 0.12 inch of water per hour for all lysimeters except Y101B. The maximum rate of percolation may be expected to occur when most of the pores, root channels, and other openings are used to transmit the gravitational water. When the soil approaches saturation, percolation rates govern infiltration rates to a large extent. Hydrograph analysis of watershed data showed that the minimum infiltration rate for the Muskingum silt loam soil was about 0.08 inch per hour, a value not greatly different from the maximum percolation rate obtained in these studies.

Percolation rates for unsaturated soils were less than for wet soils, as illustrated by the percolation for the period September 22–October 6, 1945 (fig. 43). Following an exceedingly dry late summer, percolation response to the September rainfall was slow. In fact, there was no percolation from Y103A until after 5.6 inches of rain had fallen. Likewise, 9.1 inches of rain fell in September before percolation occurred from Y101D. Percolation did not occur from Y102B until 10.2 inches of rain had fallen. Surface runoff of 1.70 inches probably prevented earlier percolation.

Average monthly percolation values for all three lysimeter batteries for the period of record (tables 26, 27, and 28) show that the highest monthly values occurred generally, in order of magnitude, in March, April, February, January, May, June, and December. In some instances percolation was higher in January than in February, and in December than in June. Generally little or no percolation was obtained during the period July to November.

Whenever unusual conditions of precipitation and other meteorological phenomena occur, percolation varies from the average pattern. This was evident in 1947 when high temperatures and high rainfall in January resulted in unusually high percolation rates for the month. Abnormally low temperatures in February and March of the same year froze the soil, and retarded percolation rates. Soil freezing affected percolation only when soil moisture was high enough to provide free or gravitational water. Under these conditions, the density of frozen soil permitted little air to enter the soil profile, thereby retarding percolation. The porous honeycomb and stalactite types of frost structure permitted more air to enter the soil than the dense concrete type, thereby providing greater air penetration and permitting a greater release of water by percolation.

The variation in percolation among lysimeters on the same soil type is due largely to soil heterogeneity and in a small degree to differences in the vegetative growth of the crops on the various lysimeters. The accumulated monthly total percolation for the years 1950–55 (fig. 37) gives a good idea of the variation in percolation among lysimeters on the same soil type. On battery Y101 the effect of soil heterogeneity overshadowed the effect of practice, as percolation was consistently higher on lysimeters Y101A and Y101C than on lysimeters Y101B and Y101D each year, 1950–55. Lysimeters Y101A and Y101B were in poor practice, whereas Y101C and Y101D were in improved (conservation) practice. Lysimeter Y101D, however, had a cover of alfalfa and bromegrass, whereas Y101C had bluegrass.

On battery Y102 all lysimeters were in conservation practice. There was greater variation in percolation among the 3 lysimeters in 1950, when rainfall was about 7 inches above normal, than in 1951. In 1952 there was considerable variation among these lysimeters, although the treatments were the same. In 1953, 1954, and 1955, lysimeters Y102B and Y102C were irrigated, whereas Y102A was not. Were it not for the fact that percolation from Y102A usually was less than from Y102B and Y102C, one might erroneously conclude that irrigation increased percolation. If it did, the result was very small.

On battery Y103 the effect of soil

heterogeneity overshadowed the effect of practice during the first 3 years of the period 1950–55. During 1953, 1954, and 1955, when rainfall was much below normal each year, percolation from lysimeters Y103A and Y103B, in conservation practice, was consistently lower than from Y103C and Y103D in poor practice. It appears that on the Keene silt loam the effect of soil heterogeneity overshadowed the effect of practice during years of normal or high percolation values. During the drier years, when precipitation and percolation were below normal, the reverse was true.

The data for years in which all lysimeters were in meadow or grass (1943, 1944, 1947, 1948, 1951, 1952, 1955) provide a good comparison of the effect of soil type on percolation. Soil-type effects may be compared for any year on Y102 and Y103 because both lysimeters were on a 4-year rotation and treatment practices were identical on Y103A and B and Y102A, B, and C. A more detailed account of the effects of soil type and land use on percolation was presented previously (*37*).

Plant nutrient losses through percolation

Losses of the chemical constituents of the soil through percolation were determined by chemical analysis of the lysimeter percolates. The loss of major plant nutrients through percolation has been studied by numerous investigators, as shown by Kohnke, Dreibelbis, and Davidson (*70*). They called attention, as have many other investigators, to the shortcomings of many lysimeters because of the unnatural conditions for percolation, the most serious being the use of filled-in lysimeters or failure to allow surface runoff.

The near-natural conditions prevailing on the Coshocton lysimeters made it possible to evaluate more accurately the plant nutrient losses resulting from the leaching process. Moreover, a knowledge of the extent of plant nutrient losses in percolation provides useful information for soil - and - water - conservation programs as well as other phases of agriculture.

Data on nutrient losses in percolates from the Coshocton lysimeters were reported by Dreibelbis and McGuinness (*40*) for the period 1940–55. Their report included a statistical interpretation of the data. The report in this bulletin is largely a summary of the data for the period 1941–55. Data on nutrient losses for different practices on the lysimeters, by years, appear in table 30. The amount of fertilizer, lime, and manure applied to each lysimeter from 1937 to 1955 is given in table 31.

It is evident that nutrient losses are generally lower on the Muskingum soils than on the Keene. For example, in 1950, a year of heavy percolation, loss of potash by leaching was 11.55 pounds per acre from lysimeter Y103 (Keene), as compared to 6.96 pounds from lysimeter Y102 (Muskingum). In 1954, a year of low percolation, the values were 2.94 pounds and 0.70 pound, respectively. Calcium losses were in the same order. This is probably a reflection of the greater permeability and better drainage characteristics of the Muskingum soil in which movement of soil water is fairly rapid. Percolation is slow in the Keene silt loam, which is characterized by a high clay content of the subsoil, and the soil solution has more opportunity to exert its solvent effect on the soil particles of the Keene than on the more rapidly drained and granular Muskingum soils. A previous study (*40*) showed that losses of potassium, calcium, magnesium, and sulfur were higher on the Keene than on the Muskingum soils, and the differences were

TABLE 30.—*Summary: Losses of nutrients through percolation, and amount of percolation water lost from lysimeter batteries Y101, Y102, and Y103, 1941–55* [1]

Year and lysimeter	Land-use practice	Nutrients lost per acre						Percolation water lost per acre
		K	Ca	Mg	N [2]	Mn	S	
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Inches*
1941:								
Y101	Poor	14. 76	(3)	2. 40	0. 40	0. 64	7. 97	11. 68
Y101	Conservation	8. 91	12. 41	2. 11	. 40	. 52	6. 09	12. 36
Y102	do	3. 63	11. 60	5. 66	2. 63	. 15	(3)	2. 61
Y103	do	8. 03	(3)	5. 66	. 49	. 12	7. 15	2. 18
Y103	Poor	19. 49	13. 80	6. 43	. 79	. 16	8. 95	2. 96
1942:								
Y101	do	9. 66	(3)	2. 20	. 38	. 73	9. 52	12. 77
Y101	Conservation	7. 37	(3)	2. 38	. 25	. 31	6. 65	13. 14
Y102	do	4. 79	11. 02	7. 94	3. 56	. 19	4. 14	4. 40
Y103	do	7. 69	(3)	4. 12	. 62	. 09	10. 87	5. 47
Y103	Poor	7. 34	21. 92	6. 06	1. 46	. 32	10. 85	5. 84
1943:								
Y101	do	8. 23	11. 24	2. 37	. 30	. 87	9. 68	12. 04
Y101	Conservation	16. 80	20. 46	9. 29	. 43	. 57	11. 08	13. 16
Y102	do	9. 51	32. 53	21. 73	6. 58	. 76	4. 53	11. 22
Y103	do	18. 73	38. 75	21. 49	2. 45	. 48	44. 38	6. 85
Y103	Poor	28. 29	30. 25	19. 27	2. 50	. 64	30. 9[illegible]	6. 38
1944:								
Y101	do	9. 78	8. 66	5. 22	. 24	. 54	6. 62	8. 32
Y101	Conservation	24. 18	17. 88	2. 77	. 36	. 50	8. 06	8. 50
Y102	do	7. 17	16. 28	13. 98	3. 72	. 34	3. 49	6. 99
Y103	do	14. 44	21. 40	18. 35	4. 02	. 34	24. 92	4. 86
Y103	Poor	18. 64	21. 80	17. 72	4. 70	. 36	19. 40	4. 82
1947:								
Y101	do	8. 66	18. 11	2. 80	. 27	. 22	18. 50	14. 73
Y101	Conservation	12. 66	20. 20	7. 20	. 50	. 14	33. 45	14. 32
Y102	do	5. 71	14. 45	9. 82	4. 06	. 16	9. 10	9. 03
Y103	do	16. 02	34. 23	24. 37	11. 82	. 14	31. 10	8. 50
Y103	Poor	22. 43	37. 07	25. 13	14. 00	. 21	27. 90	8. 74

1948:								
Y101	do	4. 83	10. 08	4. 75	. 33	(3)	(3)	12. 21
Y101	Conservation	8. 65	13. 36	7. 63	1. 13	(3)	(3)	9. 36
Y102	do	4. 15	9. 27	9. 62	2. 25	(3)	(3)	4. 67
Y103	do	8. 84	29. 79	21. 29	3. 38	(3)	(3)	5. 64
Y103	Poor	17. 47	30. 80	18. 13	6. 84	(3)	(3)	7. 93
1949:								
Y101	do	6. 49	8. 80	6. 97	. 24	(3)	(3)	13. 16
Y101	Conservation	7. 64	14. 49	7. 97	. 42	(3)	(3)	10. 30
Y102	do	5. 00	10. 95	8. 23	. 84	(3)	(3)	4. 31
Y103	do	10. 06	34. 24	25. 40	2. 47	(3)	(3)	6. 30
Y103	Poor	10. 84	24. 40	19. 45	1. 55	(3)	(3)	7. 90
1950:								
Y101	do	5. 06	15. 16	10. 43	. 37	. 30	13. 78	22. 15
Y101	Conservation	7. 88	13. 82	8. 46	. 41	. 29	26. 46	17. 68
Y102	do	6. 96	16. 95	11. 91	9. 70	. 35	23. 83	16. 03
Y103	do	11. 55	51. 79	30. 18	5. 62	. 64	82. 21	12. 61
Y103	Poor	20. 56	30. 81	18. 69	2. 87	. 94	51. 18	13. 40
1951:								
Y101	do	5. 66	10. 81	4. 86	. 18	. 20	14. 13	17. 49
Y101	Conservation	7. 99	22. 10	9. 11	. 22	. 38	34. 88	16. 40
Y102	do	7. 89	18. 13	18. 08	7. 06	. 56	29. 75	14. 82
Y103	do	9. 50	29. 91	20. 15	8. 51	. 65	55. 24	10. 22
Y103	Poor	9. 98	11. 71	9. 59	5. 01	. 62	28. 11	11. 65
1952:								
Y101	do	5. 03	10. 16	5. 87	. 23	. 26	15. 18	15. 09
Y101	Conservation	9. 92	28. 34	10. 30	. 20	. 46	28. 24	13. 37
Y102	do	4. 95	20. 00	16. 67	4. 24	. 70	25. 16	9. 54
Y103	do	9. 85	53. 31	28. 91	1. 95	. 36	48. 79	8. 65
Y103	Poor	12. 32	34. 36	17. 81	7. 19	. 46	24. 17	8. 43
1953:								
Y101	do	1. 67	2. 36	. 30	. 12	. 23	6. 61	9. 77
Y101	Conservation	1. 97	2. 54	. 37	. 12	. 28	12. 39	5. 55
Y102	do	. 80	1. 46	. 22	. 41	. 11	6. 34	1. 46
Y103	do	2. 77	5. 88	. 74	. 64	. 13	8. 27	3. 54
Y103	Poor	3. 61	4. 59	. 68	1. 18	. 19	12. 51	5. 05

See footnotes at end of table.

TABLE 30.—*Summary: Losses of nutrients through percolation, and amount of percolation water lost from lysimeter batteries Y101, Y102, and Y103, 1941–55* [1]—Continued

Year and lysimeter	Land-use practice	Nutrients lost per acre						Percolation water lost per acre
		K	Ca	Mg	N [2]	Mn	S	
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Inches*
1954:								
Y101	Poor	.97	1.30	.85	.11	.14	4.26	6.22
Y101	Conservation	1.71	2.43	1.00	.25	.08	3.85	3.72
Y102	do	.70	1.55	1.32	1.16	.06	1.95	1.59
Y103	do	2.94	4.28	2.42	1.58	.05	4.05	1.54
Y103	Poor	6.04	6.62	3.99	2.88	.14	6.54	3.40
1955:								
Y101	do	2.52	2.74	2.03	.22	.27	7.05	9.73
Y101	Conservation	2.95	4.45	2.34	.16	.19	8.20	6.24
Y102	do	2.67	5.90	8.44	7.65	.19	8.03	6.92
Y103	do	4.95	10.89	12.20	2.34	.19	24.25	5.68
Y103	Poor	7.54	9.84	6.85	2.29	.29	20.20	7.65
Average: [1]								
Y101	do	6.41	9.04	3.93	.26	.40	10.30	12.72
Y101	Conservation	9.13	14.37	5.46	.37	.34	16.30	11.08
Y102	do	4.92	13.08	10.28	4.14	.32	11.63	7.20
Y103	do	9.64	28.59	16.56	3.53	.29	31.02	6.31
Y103	Poor	14.20	21.38	13.06	4.10	.39	21.88	7.24

[1] Data for 1945 and 1946 omitted because of incomplete records.

[2] Nitrate nitrogen.

[3] No data.

TABLE 31.—*Application of fertilizer, lime, and manure, 1937–55*

Year and lysimeter	Fertilizer: Amount per acre	Fertilizer: Kind	Lime per acre	Manure per acre
	Pounds		*Tons*	*Tons*
1937:				
Y101	0		0	0
Y102	0		0	8
Y103	0		0	0
1938:				
Y101	0		0	0
Y102	125	2–12–6	0	0
Y103	175	2–12–6	0	0
1939:				
Y101	0		0	0
Y102	100	0–20–0	0	0
	150	0–16–0		
	10	20–0–0		
Y103	100	0–20–0	0	0
	150	0–16–0		
	10	20–0–0		
1940:				
Y101	0		0	0
Y102	0		0	0
Y103	0		0	0
1941:				
Y101	0		0	0
Y102	500	2–12–6		8
Y103A, B	500	2–12–6		4
Y103C, D	200	2–12–6		4
1942:				
Y101	0		0	0
Y102	0		0	0
Y103A, B	0		0	4
Y103C, D	0		0	0
1943:				
Y101	0		0	0
Y102	0		0	0
Y103	0		0	0
1944:				
Y101	0		0	0
Y102	0		2.5	6
Y103A, B	0		2.5	6
Y103C, D	0		0	6
1945:				
Y101A, B	0		0	0
Y101C, D	500	2–12–6	3	4
Y102	500	2–12–6	2	0
Y103A, B	500	2–12–6	2	0
Y103C, D	200	2–12–6	0	0
1946:				
Y101A, B	0		0	0
Y101C, D	400	0–20–0	2	0
Y102	0		0	4
Y103A, B	0		0	4
Y103C, D	0		0	0

TABLE 31.—*Application of fertilizer, lime, and manure, 1937–55*—Con.

Year and lysimeter	Fertilizer		Lime per acre	Manure per acre
	Amount per acre	Kind		
	Pounds		*Tons*	*Tons*
1947:				
Y101A, B	0	-----	0	0
Y101C, D	500	3–12–12	0	0
Y102	200	0–12–20	0	0
Y103A, B	200	0–12–20	-----	-----
Y103C, D	0	-----	0	0
1948:				
Y101	0	-----	0	0
Y102	0	-----	0	0
Y103	0	-----	0	0
1949:				
Y101	0	-----	0	0
Y102	600	3–12–12	0	6
Y103A, B	600	3–12–12	0	6
Y103C, D	300	2–12– 6	0	6
1950:				
Y101C, D	500	4–12– 8	0	0
Y102	0	-----	0	4
Y103A, B	0	-----	0	4
1951:				
Y101C	80	Nitrate	0	0
Y102	150	0–10–30	0	0
Y103	150	0–10–30	0	0
1952:				
Y101C, D	500	3–12–12	0	0
Y102	0	-----	1	0
Y103A, B	0	-----	1	0
1953:				
Y101C	400	8– 8– 8	0	0
	300	3–12–12	0	6
Y102	80	Nitrate	0	0
	300	3–12–12	0	0
Y103A, B	300	3–12–12	0	6
Y103C, D	100	3–12–12	0	0
Y103A, B	300	3–12–12	0	0
Y103C, D	100	3–12–12	0	0
1954:				
Y101	0	-----	0	0
Y102	0	-----	0	4
Y103A, B	0	-----	0	4
1955:				
Y101	0	-----	0	0
Y102	200	0–10–30	0	0
Y103A, B	200	0–10–30	0	0

all highly significant. Losses of nitrogen and manganese were higher on the Muskingum, but the differences were not significant.

Calcium exceeded other nutrients in total amount lost through percolation. More calcium was lost under conservation practice than under poor practice, because of the addition of limestone to the soil on the former. In the wet year 1950, calcium leaching totaled 51.79 pounds per acre from Y103 (conservation practice) and 30.81 pounds from Y103 (poor practice). In the dry years 1953 and 1954, losses were about 5 pounds per acre under both practices, and were not significantly different.

Magnesium losses were also generally higher under conservation practice. When the loss was higher under poor practice, it was because percolation was greater from these areas during those years.

The percolates contained less potassium (K) than calcium and in many cases less potassium than magnesium. On the Keene silt loam the loss of K was greater under poor practice than under conservation practice. This was probably due in part to the repressive effect of the added limestone (conservation practice) on the outgo of K; also, on the conservation areas, to the increased vegetation which utilized more K. Although greater amounts of K were applied on the conservation-practice lysimeters, it is likely the opportunity for absorption and fixation of K was great enough to limit the amount of K in the percolates.

Nitrogen occurs in the percolate mostly, if not entirely, in the form of nitrate, and in this study it was determined only as such. A summary of the data on nitrates in the percolates from each lysimeter for the period 1940–55 appears in table 32. These data show the contrast in nitrogen losses in percolates by soil type and by practice, and the variation in nitrogen losses from lysimeters on the same soil type. Nitrate losses were least on the Muskingum silt loam lysimeters over sandstone that were in permanent grass; annual values ranged from zero to 2.09 pounds per acre. On the 4-year rotation lysimeters there was no statistical difference between the nitrogen losses from the Keene and from the Muskingum soils (*40*). Variation in nitrogen losses was less between practices than among lysimeters on the same practice. The variation in nitrogen losses was considerable from year to year; annual values ranged from 0.03 to 14.85 pounds per acre. This variation was influenced mostly by the amount of percolate and by the addition of nitrogen in fertilizer and in manure.

The amount of manganese found in the percolates is small but appreciable. The amounts needed in plant nutrition are likewise small. Manganese losses were generally lower under conservation practice than under poor practice, largely because the limestone applications on the former tended to reduce the solubility of manganese.

Sulfur losses were considerably higher from lysimeters on the Keene soil than from lysimeters on the Muskingum soil. This difference was likely due to the greater sulfur contamination of the atmosphere at the Keene location. Smoke from soft coal fire in the station garage furnace has been observed to blow over lysimeter battery Y103 throughout the winter, thus providing the greater-than-normal sulfur contamination. Sulfur losses were generally higher on the conservation-practice lysimeters, largely because of the sulfur added in fertilizer.

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TABLE 32.—*Summary of data on nitrates in lysimeter percolates, 1940–55 (in pounds of N per acre per year)*

Year	Lysimeter Y101				Lysimeter Y102			Lysimeter Y103			
	A	B	C	D	A	B	C	A	B	C	D
1940	0. 27	0. 30	(1)	(1)	6. 53	6. 62	5. 76	(1)	(1)	4. 48	4. 25
1941	. 44	. 36	0. 40	(1)	2. 72	2. 53	(1)	0. 23	0. 75	. 72	. 87
1942	. 40	. 35	. 25	(1)	2. 76	2. 93	4. 98	. 29	. 96	1. 84	1. 09
1943	. 40	. 19	. 43	(1)	5. 40	4. 71	9. 63	3. 39	1. 52	3. 58	1. 42
1944	. 31	. 17	. 36	(1)	2. 87	2. 86	5. 44	6. 23	1. 80	3. 44	5. 95
1945	1. 22	. 22	. 62	2. 09	2. 25	2. 03	6. 93	5. 04	. 46	2. 99	5. 74
1946	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
1947	. 40	. 14	. 20	. 81	1. 52	3. 07	7. 58	14. 85	8. 79	14. 53	13. 46
1948	. 47	. 18	. 39	1. 86	1. 26	1. 91	3. 57	4. 55	2. 22	10. 44	3. 23
1949	. 32	. 15	. 41	. 43	. 59	. 73	1. 19	3. 25	1. 68	1. 70	1. 41
1950	. 50	. 23	. 67	. 15	8. 22	8. 01	12. 87	5. 15	6. 08	2. 37	3. 36
1951	. 21	. 15	. 31	. 13	8. 40	5. 88	6. 89	14. 24	2. 77	2. 66	7. 35
1952	. 34	. 13	. 33	. 08	3. 31	3. 62	5. 77	2. 21	1. 68	3. 93	10. 44
1953	. 13	. 12	. 17	. 07	. 03	. 07	1. 14	. 56	. 73	. 60	1. 76
1954	. 22	. 29	. 21	0	. 03	. 42	3. 03	. 86	2. 31	1. 64	4. 12
1955	. 30	. 15	. 32	. 01	6. 23	6. 34	10. 37	2. 03	2. 66	1. 96	2. 63
Average (years of data)	. 40	. 21	. 36	. 56	3. 47	3. 45	6. 08	4. 49	2. 46	3. 79	4. 47

[1] No data.

The nutrients applied to the soil in the form of fertilizer, manure, and lime may appear in the percolates the same year or in one of the following years. Thus it is difficult to attribute nutrient losses to any particular crop. Also, the concentration of nutrients in the percolation water is not necessarily constant over any period.

The nutrients in drainage water were derived mainly from the applied manure, fertilizer, and limestone materials and from the soil itself. Contaminants in the atmosphere contribute a small but appreciable amount. The rate of nutrient loss per unit volume of percolation was always lower on the poor-practice lysimeters than on the conservation-practice lysimeters.

Nutrient Losses by Leaching Vary With Rainfall

Data on nutrient losses for 1950 (a year of high precipitation) and 1953 (a year of low precipitation) are given in table 33 to show the wide differences in losses under these extremes in rainfall. In 1953 (low rainfall) small amounts of percolation and minimum values of leaching were obtained. In 1950 both rainfall and percolation were much above normal. Nutrient-loss data for this year may, therefore, be close to the maximum likely to occur under the climatic and fertility conditions prevailing at the Coshocton station. The data also reveal the influence of improved conservation practices on nutrient losses during these wet and dry years.

In 1950, annual rainfall was 47.28 inches, over 7 inches above normal, and calcium losses were over 51 pounds per acre. This is equivalent to approximately 130 pounds of calcium carbonate. In 1953, annual rainfall was only 28.20 inches, 11 inches below normal, and calcium losses were only 5.88 pounds per acre. Average calcium losses for the 16-year period 1941–55 were 29.35 pounds. Percolation amounted to 12.61 inches in 1950 and 3.54 inches in 1953. Magnesium losses for the 2 years showed an even greater contrast. The other elements studied (K, N, Mn, and S) also showed a very noticeable contrast in losses for the 2 years.

The observation that excessive water supply resulted in large increases in nutrient leaching is important in irrigation practice. If excessive amounts of water are applied, greater nutrient losses through percolation may result. Also, in the humid region, rainfall sometimes occurs soon after irrigation. The excessive amount of water in the soil under such conditions may result in an increase in nutrient losses by leaching.

The difference in nutrient losses between conservation-practice and poor-practice lysimeters was less than between the years of high and low rainfall. Increased rates of fertilizer applications on conservation-practice lysimeters resulted in some sizable increases in leaching losses in the wet year. Higher fertilizer rates generally used in irrigation practice could, therefore, result in noticeable increases in leaching losses whenever such practices caused a greater amount of percolation.

Although annual losses of plant nutrients through percolation were appreciable, they were small compared to losses through surface runoff. Data from the Coshocton lysimeters indicate that nutrient losses through drainage are less than formerly supposed. Many of the data from earlier studies were obtained under unnatural conditions because of the use of filled-in lysimeters.

TABLE 33.—*Plant nutrient losses in lysimeter percolates on Keene silt loam during a period of high precipitation (1950) and low precipitation (1953), as compared with the 16-year average (1940–55), by practice*

Practice and period	Total precipitation	Percolation	Nutrients percolated per acre					
			Ca	Mg	K	N	Mn	S
	Inches	*Inches*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Conservation:								
1950 (high precipitation)	47. 28	12. 61	51. 79	30. 18	11. 55	5. 62	0. 64	82. 21
1953 (low precipitation)	28. 20	3. 54	5. 88	. 74	2. 77	. 64	. 13	8. 28
16-year average (1940–55)	37. 16	6. 29	29. 35	17. 61	9. 74	3. 47	. 30	31. 42
Poor:								
1950 (high precipitation)	47. 28	13. 40	30. 81	18. 69	20. 56	2. 87	. 94	51. 18
1953 (low precipitation)	28. 20	5. 04	4. 59	. 68	3. 61	1. 18	. 19	12. 51
16-year average (1940–55)	37. 16	7. 20	21. 04	12. 29	13. 41	4. 13	. 37	20. 89

DISCUSSION OF RESULTS

This bulletin presents a complete evaluation of various important factors of agricultural hydrology obtained over a period of 12 years (1944–55) by the Coshocton monolith lysimeters. Some summaries from 1938 are included. For the last 3 years (1953–55) irrigation on lysimeters Y102B and Y102C prevented moisture deficiencies from affecting the water consumptive-use values by crops. Lysimeter Y103A was not irrigated. Results from the unirrigated lysimeters are believed to approximate closely those that prevail under natural conditions. Results from the irrigated lysimeters are expected to represent adequately the hydrology of irrigation farming for similar crops and climate.

The self-recording features of the lysimeter, including the unique weighing mechanism, made it possible to evaluate the various forms of accretion and depletion of soil moisture as well as water storage changes within the soil block. Monthly and annual summaries of precipitation, condensation, runoff, percolation, and evapotranspiration provide data for a permanent cover of grass and legumes and for a 4-year rotation consisting of corn, wheat, and 2 years of meadow. The daily fluctuations of soil moisture, when summarized separately in terms of the various forms of accretion, depletion, and storage of soil water, provide data of much value in the solution of numerous problems in agricultural hydrology.

By means of the weighing recording mechanism, it was possible to evaluate the hourly weight of moisture vapor transferred from the atmosphere to liquid form on the earth — condensation–absorption (CA). CA compensates for some of the water lost to the atmosphere during the day — evapotranspiration (ET). The net daily loss of soil moisture, commonly termed consumptive use or evapotranspiration, is derived by ET−CA.

Atmospheric moisture is the supply of water to the earth's surface; precipitation accounts for about 80 percent of this supply and CA for the remainder. For example, in 1948, precipitation totaled 42.04 inches and CA, 11.68 inches. The individual monthly values of CA, when unaffected by drifting snow, ranged from 0.07 to 1.56 inches and averaged from 0.5 to 0.6 inch per month. Although much of this water was returned to the atmosphere by evaporation after a few hours of sunshine, the data indicated that CA reduced the depletion of soil moisture. CA was greater on dry, unirrigated soils than on moist irrigated soils. In the dry month of August 1951 on lysimeter Y103A, rainfall totaled 0.75 inch and CA, 1.39 inches. There were 8 days that month when CA was 0.05 inch or greater.

Removal of water from the soil or from the vegetation by evapotranspiration (ET) was greatest during the hot summer months, exceeding 7 inches per month several times and reaching 8.14 inches in July 1951 on lysimeter Y101D. The net moisture depletion (ET−CA) represents water *consumptive use* by crops—a term common to irrigation practice. ET−CA for July 1951 on lysimeter Y101D was 8.14 minus 0.39, or 7.75 inches. Seasonal variations in ET−CA are shown graphically along with daily fluctuations in soil moisture. They indicate the high rates of consumptive use and the resultant loss of soil moisture. Soil-moisture deficits in the mid and late growing season are shown to reduce the rates of ET−CA. Cutting of hay reduced rates of ET−CA for several days, after which there was usually a return to rates prior to cutting. After the second cutting of hay the rates never reached the magnitude of those prior to cutting.

The differences between cornland and grassland (alfalfa-bromegrass) in ET—CA and their effect on soil moisture for May and June in 1949 and 1953 were striking. Soil moisture on July 1 in the 40-inch root zone was 4 to 5 inches less on the grass lysimeter than on the corn lysimeter. Moisture losses were materially less from nearly-bare cornland than from alfalfa-bromegrass. Consumptive-use rates in July and August were nearly the same for both lysimeters. By this time, the corn plants had developed a complete canopy over the land surface.

An examination of soil-moisture records for various sections of the profile indicated that the greatest fluctuations occurred in the 0- to 7-inch depth. On the unirrigated plot, moisture extraction by meadow or corn below the 7-inch depth was very noticeable, especially during dry periods. On the irrigated plots, moisture extraction below the 7-inch depth was less evident as long as there was ample moisture in the 7-inch layer. Even on the irrigated corn plots there were times in August when the moisture in the 7-inch top soil depleted to about 20 to 10 percent by volume. Then moisture-extraction rates in the 7- to 14-inch and 14- to 24-inch depths were high.

Evapotranspiration data from the cropped lysimeters show the amount of water used in producing crops and the efficiency of this water use. For a corn crop, water used in the 5-month growing season ranged from 17.4 to 24.6 inches. In general, the lower water-use values correspond to the lesser yield values. The highest water-use value, 24.6 inches, corresponded to a yield of 139 bushels per acre (unirrigated) in 1949. It is interesting to note that a higher yield was obtained under irrigation in 1953, when actually a lower unit quantity of water was used. It is possible that water-use efficiency is greater in a planned water-application program than when nature supplies the water at random. The weight of water used to produce a pound of crop under irrigation in 1953 was 273 pounds, whereas 395 pounds was used in 1949.

The yield of first-year hay (red clover-alfalfa-timothy) in two cuttings was 5.97 tons on irrigated lysimeter Y102C. For the period April 1 to July 22 (the time of the second hay cutting) water-use efficiency was 383 pounds of water to produce a pound of hay. Water-use for the 5-month growing period April–September, was 27 inches, an efficiency value of 513 pounds per pound of crop.

Average ET—CA values for the various months of the growing season for different crops are compared with average values for maximum 10-day use periods during each month. In some cases, an engineer may want to design irrigation systems on the basis of the maximum 10-day use rather than on the monthly average. Differences were very apparent. ET—CA was as low as 0.14 inch per day in some periods. That for a 10-day period reached 0.36 inch per day. Average for the month was 0.22 inch per day.

Lysimeter ET—CA is compared with water-surface pan evaporation and with atmometer data. The latter two are some measure of the energy forces causing transfer of moisture to the atmosphere. There does not appear to be any constant relationship either for all crops or for the entire growing season. This is perhaps as it should be, varying according to the development of ground cover by vegetal leaf area and according to available soil-moisture supplies. The results appear to be encouraging, yet indicate the need for more data. Perhaps by means of evaporation-pan factors, the lysimeter ET—CA values can be used in climatic areas other than that at Coshocton.

Percolation data from the lysimeters provide a means of evaluating the monthly, seasonal, and yearly recharge to ground water for the Coshocton soil types and for different crops. As expected, the period of percolation coincides with the period of highest soil-moisture content, with about 80 percent of the annual percolation occurring in the January–April period. With the rapid extraction of soil moisture beginning in May, there is less and less water available for percolation as the growing season progresses.

The greatest amount of percolation in any one calendar year was 26.37 inches from lysimeter Y101C in bluegrass. The least was zero from Y101D in alfalfa-bromegrass. Bluegrass, being shallow rooted, extracted moisture from only a thin layer of surface soil, whereas the deep roots of alfalfa and bromegrass removed soil moisture to depths of several feet. Moisture recharge, in the year of zero percolation, was not enough to provide free or gravitational water at the bottom of the 8-foot lysimeter profile.

Plant nutrient losses through percolation are evaluated from samples taken frequently throughout the year. Calcium (Ca) losses are larger than losses of any other nutrient. They amounted to 51.79 pounds per acre in 1950. In the dry years 1953 and 1954, calcium losses totaled only about 5 pounds per acre per year. Potassium (K) losses ranged from less than 1 pound to over 28 pounds per acre per year. Nitrate (N) losses ranged from less than 1 pound to 14 pounds per acre per year.

The weighing lysimeter is a unique rain gage. It has a catchment area of 12,540 square inches compared with an area of 50-square inches for the United States Weather Bureau Fergusson gage. Lysimeter weight records, are accurate to 0.01 inch. Annual precipitation values averaged about 4 inches greater from the lysimeter than from the rain gage. The maximum difference was 9.60 inches in 1951. Only 2.68 of the 9.60 inches could be attributed to rainstorms; the remainder—the major difference—is attributed to snow. The Fergusson gage, unshielded, is not recognized as a reliable snow gage. A study of the daily storm rainfall for storms of 0.1 inch or greater indicated no consistent trend in rainfall catch between the two types of measurements. Only in 1950 were the daily values fairly consistently less from the Fergusson gage than from the lysimeter, and then the difference was about 10 percent.

Although the rain gage is of questionable accuracy, no other instrument capable of providing the needed information as economically is available. Furthermore, areal variations in storm rainfall at times are believed to be much greater than the errors referred to above. At this station the catch in a single rain gage is used to represent rainfall on drainage basins up to 40 acres. For some hydrologic studies, the record from a single rain gage is used to represent thousands of square miles. In applying data from a single gage to large areas, the inaccuracies of the gage itself can possibly be ignored.

The complete lysimeter data cover a relatively short period; data for 12 years with a 4-year rotation give only 3 replications. Although the findings may be considered tentative, they illustrate principles and can be of material use in agricultural hydrology. Further sampling in seasons with extreme climatic variations may modify the results.

Water control and utilization problems are numerous and varied. The adequate solution of these problems requires the proper use and treatment of the land with consideration of the hydrologic balance including precipitation, condensation, absorption, runoff, percolation, evapotranspiration, and moisture-storage changes. The data contained in this report can be used to help solve many phases of these and related water-control problems.

LITERATURE CITED

(1) ALLISON, L. E., and REEVE, R. C.
1955. LYSIMETERS FOR STUDYING EFFECTS OF SALINITY, LEACHING, AND POSITION OF WATER TABLE ON PLANT GROWTH. Soil Sci. 79: 81–91, illus.

(2) ANNETT, H. E.
1951. LOSS OF SOIL NUTRIENTS IN DRAINAGE. Specialist Conf. in Agr. (Plant and Anim. Nutr. in Relation to Soil and Climatic Factors), Adelaide and Canberra, Australia, Aug. 22–Sept. 15, Proc. 1949: 244–245.

(3) ARRHENIUS, O.
1952. THE CHEMICAL DENUDATION OF THE SOIL. Tellus [Stockholm] 4: [307]–310, illus. [In English.]

(4) ASLYNG, H. C., and KRISTENSEN, K. J.
1953. INVESTIGATIONS ON THE WATER BALANCE IN DANISH AGRICULTURE. Copenhagen, Veterinaerog Landbohøjsk. Årsskr. (Yearbook, Annu., Jahrb.) 1953: [48]–90, illus. [In English.]

(5) BASTISSE, E. M.
1949. OBSERVATIONS EN CASES LYSIMÉTRIQUES POUR 1948 17^{e} ANNÉE. Ann. Agron. [Paris] (n. s.) 19: 659–664. (*In* [Recherches sur la Fertilisation en 1948.], pp. 658–745, illus.)

(6) ———
1951–53. DIX-HUIT ANNÉES D'ÉTUDES LYSIMÉTRIQUES APPLIQUÉES A L'AGRONOMIE. PREMIER [ET DEUXIÉME] MÉMOIRE. [France] Min. de l'Agr., Inst. Natl. de la Rech. Agron., Ann., Ser. A. Ann. Agron. 2: [727]–781, illus., 1951; 4: 53–76, 331–378, 519–560, 717–780, illus., 1953.

(7) ——— and HENIN, S.
1955. DIX HUIT ANNÉES D'ÉTUDES LYSIMÉTRIQUES APPLIQUÉES A L'AGRONOMIE. TROISIÉME MÉMOIRE. RÉSULTATS GÉNÉRAUX OBTENUS POUR LES DIX-HUIT ANNÉES D'OBSERVATIONS EN CASES LYSIMÉTRIQUES. [France] Min. de l'Agr., Inst. Natl. de la Rech. Agron., Ann., Ser. A, Ann. Agron. 6: 203–232, illus.

(8) BENJAMINSEN, J.
1954. UNDERSØGELSER OVER UDVASKNINGEN AF FOSFORSYRE OG KALIUM I FORSKELLIGE JORDTYPER. Tidsskr. for Planteavl. 57: [99]–107, illus.

(9) BIZZELL, J. A.
1943. LYSIMETER EXPERIMENTS—V. COMPARATIVE EFFECTS OF AMMONIUM SULFATE AND SODIUM NITRATE ON REMOVAL OF NITROGEN AND CALCIUM FROM THE SOIL. N. Y. (Cornell) Agr. Expt. Sta. Mem. 252, 24 pp., illus.

(10) ———
1944. LYSIMETER EXPERIMENTS—VI. THE EFFECTS OF CROPPING AND FERTILIZATION ON THE LOSSES OF NITROGEN FROM THE SOIL. N. Y. (Cornell) Agr. Expt. Sta. Mem. 256, 14 pp.

(11) BOSCHI, V.
1954. RICERCHE SULL'IRRIGAZIONE DI SOCCORSO IN CASSE DA VEGETAZIONE LISIMETRICHE. [Italy] Min. dell'Agr. e Foreste, Ann. della Sper. Agr. (n. s.) 8: 1117–1139, illus. [English summary, Research on Auxiliary Irrigation in Lysimetric Tanks, p. 1138.]

(12) BROADBENT, F. E., and CHAPMAN, H. D.
1950. A LYSIMETER INVESTIGATION OF GAINS, LOSSES, AND BALANCE OF SALTS AND PLANT NUTRIENTS IN AN IRRIGATED SOIL. Soil Sci. Soc. Amer. Proc. (1949) 14: 261–269.

(13) BRUIN, P.
1952. HET BELANG VAN LAND-, TUIN- EN BOSBOUW BIJ LYSIMETERONDERZOEK. Nederlandse Cent. Organ. v. Toegepast-Natuurw. Onderzoek, Commis. v. Hydrol. Vyslag. Tech. Bijeenk. (1946–50) 1/6: [154]–162. [English summary, The Importance of Lysimeter Investigations for Agriculture, Horticulture and Forestry, pp. 291–292; French summary pp. 320–321.]

(14) Bryssine, G.
[1951.] HUMIDITE ET POSSIBILITE DE LESSIVAGE DES SOLS AU MAROC (RABAT). Trans. 4th Internatl. Cong. Soil Sci., Amsterdam, July 24-Aug. 1, 1950, 1: 64-66. [English summary p. 66.]

(15) Carrante, V., Di Prima, S., and Bòttari, V.
1951. TERZO CONTRIBUTO ALLE ESPERIENZE PERMANENTI DI CONCIMAZIONE DEGLI AGRUMI. (TRIENNIO 1947-49.) [Italy] Min. dell'Agr. e Foreste, Ann. della Sper. Agr. (n. s.) 5: 679-720, illus. [English summary, Third Contribution to the Permanent Experiments on the Fertilizing of Citrus Trees. (Period 1947-49), p. 713.]

(16) Cavanillas Rodriguez, L.
1946. ESTUDIOS DE TRANSPIRACION VEGETAL. EXPERIENCÍAS EN LISÍMETROS CON CULTIVO DE PATATAS. [Spain] Inst. Españ. de Edafol., Ecol. y Fisiol. Veg. An. 5: [441]-453, illus. [English and French summaries p. 453.]

(17) ———
1948. ESTUDIOS SOBRE TRANSPIRACION VEGETAL. EXPERIENCÍAS CON TRIGO CULTIVADO EN LISÍMETROS. [Spain] Inst. Españ. de Edafol., Ecol. y Fisiol. Veg. An. 7: [187]-200, illus.

(18) ———
1949. ESTACIONES DE LISÍMETROS. [Spain] Inst. Nac. de Invest. Agron. Bol. 20, pp. [211]-234, illus.

(19) Cavanillas Rodriguez, L.
1950. IRRIGATION REQUIREMENTS IN SPAIN. Research 3: 365-369, illus.

(20) ———
1951. EXPERIENCÍAS EN LISÍMETROS. [Spain] Inst. Nac. de Invest. Agron. Bol. 24, pp. [211]-221.

(21) ——— and Angulo Carpio, D.
1946. ESTUDIOS DE TRANSPIRACION VEGETAL. I. EXPERIENCÍAS EN LISÍMETROS CON CULTIVOS DE JUDÍAS. II. RELACIÓN ENTRE LA ESTRUCTURA FOLIAR Y LA TRANSPIRACIÓN. [Spain] Inst. Españ. de Edafol., Ecol. y Fisiol. Veg. An. 5: [65]-92, illus. [English and French summaries p. 92.]

(22) Chapman, H. D.
1955. APPARENT FERTILITY TRENDS IN WESTERN IRRIGATED SOILS. Better Crops with Plant Food 39 (2): 11-12, 40-41.

(23) ——— and Harding, R. B.
1955. WHAT IS HAPPENING TO OUR CITRUS SOILS? Better Crops with Plant Food 39 (5): 11-14, 40-44, illus.

(24) ——— Liebig, G. F., and Rayner, D. S.
1949. A LYSIMETER INVESTIGATION OF NITROGEN GAINS AND LOSSES UNDER VARIOUS SYSTEMS OF COVER-CROPPING AND FERTILIZATION, AND A DISCUSSION OF ERROR SOURCES. Hilgardia 19: 57-128, illus.

(25) Colman, E. A.
1946. A LABORATORY STUDY OF LYSIMETER DRAINAGE UNDER CONTROLLED SOIL MOISTURE TENSION. Soil Sci. 62: 365-382, illus.

(26) ——— and Hamilton, E. L.
1947. THE SAN DIMAS LYSIMETERS. U. S. Forest Serv., Calif. Forest and Range Expt. Sta. Forest Res. Notes 47, 33 pp., illus. [Processed.]

(27) Davis, D. E., MacIntire, W. H., Comar, C. L., and others.
1953. USE OF CA45 LABELED QUENCHED CALCIUM SILICATE SLAG IN DETERMINATION OF PROPORTIONS OF NATIVE AND ADDITIVE CALCIUM IN LYSIMETER LEACHINGS AND IN PLANT UPTAKE. Soil Sci. 76: 153-163.

(28) Deij, L. J. L.
1951. THE LYSIMETER STATION AT CASTRICUM (HOLLAND). Proc.-Verb. Hydrol., 8th Gen. Assembly Internatl. Union Geod. and Geophys., Oslo, Norway, Aug. 19-28, 1948, 3: 11-15. (Ref. in Amer. Geophys. Union Trans. 32: 622. 1951. [Processed.])

(29) ———
1952. EEN NIEUWE METHODE TER BEPALING VAN DE VERDAMPING VAN HET BODEMWATER. Nederlandse Cent. Organ. v. Toegepast-Natuurw. Onderzoek, Commis. v. Hydrol. Verslag.-Tech. Bijeenk. (1946-50) 1/6: [18]-19. [English summary, A New Method to Determine the Evaporation of Water in the Soil, pp. [279]-281; French summary pp. [307]-309.]

(30) DEMOLON, A., and BASTISSE, E. M.
1942. ÉTUDES LYSIMÉTRIQUES APPLIQUÉES À L'AGRONOMIE. Versailles, Centre Natl. de Rech. Agron. 48 pp., illus. (At head of title (abbrev.): État Francais, Min. de l'Agr. et du Ravitaile., Dir. de l'Enseig. et des Rech.)
(31) ——— and BASTISSE, E. M.
1943. OBSERVATIONS EN CASES LYSIMÉTRIQUES. (11e ANNÉE). Etat. Francais, Min. de l'Agr. et du Ravitaille., Recherches sur la Fertilisation Effectuées en 1942 par les Stations Agronomiques (XVIe Rapport Annuel), pp. 10–17.
(32) DIMO, N. A.
1949. [THE EFFECTIVENESS OF THE FIRST YEAR OF LEACHING LOAM SOILS.] Leningrad Akad. Selsk. Khoz. Nauk Dok. 14 (6): 73–77. [In Russian. English title and abstract in Commw. Bur. Soil Sci., Soils and Fert. 13: 167. 1950.]
(33) DOORN, Z. VAN.
1951. EEN HYDROLOGISCHE WAARNEMING AAN DE LYSIMETERS VAN HET P.W.N. TE CASTRICUM. Water 35: 23–25. [English summary p. 25. A HYDROLOGICAL OBSERVATION WITH LYSIMETERS OF THE P.W.N. AT CASTRICUM; English title and abstract in Commw. Bur. Soil Sci., Soils and Fert. 16: 122–123. 1953.]
(34) DREIBELBIS, F. R.
1947. SOME PLANT NUTRIENT LOSSES IN GRAVITATIONAL WATER FROM MONOLITH LYSIMETERS AT COSHOCTON, OHIO. Soil Sci. Soc. Amer. Proc. (1946) 11: 182–188, illus.
(35) ———
1947. WHAT BECOMES OF OUR RAINFALL? Jour. Soil and Water Conserv. 2: 97–101, 108, illus.
(36) ———
1949. SOME INFLUENCES OF FROST PENETRATION ON THE HYDROLOGY OF SMALL WATERSHEDS. Amer. Geophys. Union Trans. 30: 279–282, illus. [Processed.]
(37) ———
1954. SOIL TYPE AND LAND USE EFFECTS ON PERCOLATION OF SOIL WATER THROUGH MONOLITH LYSIMETERS. Soil Sci. Soc. Amer. Proc. 18: 358–362, illus.
(38) ——— and BENDER, W. H.
1953. A STUDY OF SOME CHARACTERISTICS OF KEENE SILT LOAM AND MUSKINGUM SILT LOAM. Jour. Soil and Water Conserv. 8: 261–266, illus.
(39) ——— and HARROLD, L. L.
1946. A SUMMARY OF PERCOLATION AND OTHER HYDROLOGIC DATA OBTAINED FROM THE COSHOCTON MONOLITH LYSIMETERS. Soil Sci. Soc. Amer. Proc. (1945) 10: 451–457, illus.
(40) DREIBELBIS, F. R. and MCGUINNESS, J. L.
1957. PLANT NUTRIENT LOSSES IN LYSIMETER PERCOLATES. Agron. Jour. [In press.]
(41) ——— and POST, F. A.
[1942.] AN INVENTORY OF SOIL WATER RELATIONSHIPS ON WOODLAND, PASTURE, AND CULTIVATED SOILS. Soil Sci. Soc. Amer. Proc. (1941) 6: 462–473, illus.
(42) ——— and POST, F. A.
1944. SOME SEASONAL CHANGES IN THE PORE SPACE AND MOISTURE RELATIONSHIPS OF WOODLAND, PASTURE, AND CULTIVATED SOILS. Soil Sci. Soc. Amer. Proc. (1943) 8: 102–108, illus.
(43) DROVER, D. P., and BARRETT-LENNARD, I. P.
1953. A FIRST REPORT ON NITROGEN LOSSES FROM LYSIMETERS—MURESK, WESTERN AUSTRALIA Austral. Conf. Soil Sci., Adelaide, June 1953, Summaries of Papers 1: 2.13.1–2.13.4. [Processed.]
(44) FRIEDRICH, W.
1950. DIE BEDEUTUNG VON LYSIMETERVERSUCHEN FUR DIE GRUNDWASSERKUNDE. GWF: Gas- u. Wasserfach., ausg. Wasser, 91: 197.
(45) ———
1950. ÜBER DIE VERDUNSTUNG VOM ERDBODEN. ZUSAMMENFASSENDER BERICHT ÜBER DIE EBERSWALDER LYSIMETERMESSUNGEN. GWF: Gas- u. Wasserfach., ausg. Wasser, 91: [289]–296, illus.

(46) FRIEDRICH, W.
1954. LYSIMETERMESSUNGEN UND ANDERE GEWÄSSERKUNDLICHE VERFAHREN ZUR ERMITTLUNG DER GRUNDWASSERERNEUERUNG. Ztschr. der Deut. Geol. Gesell. 106: [41]-48, illus.

(47) GALVEZ, N. L., and BUENO, P. M.
1951. RESIDUAL EFFECT OF AMMONIUM SULFATE FERTILIZER WITH RICE AS INDICATOR. Philippine Agr. 35: 75-81, illus.

(48) GEERING, J.
1943. LYSIMETER-VERSUCHE. Landw. Jahrb. der Schweiz 57: [107]-182, illus. [French summary p. 182.]

(49) GRUYTER, P. DE.
1952. HET WATERSTAATKUNDIG BELANG BIJ LYSIMETERONDERZOEK. Nederlandse Cent. Organ. v. Toegepast-Natuurw. Onderzoek, Commis. v. Hydrol. Verslag. Tech. Bijeenk. (1946-50) 1/6: [141]-153, illus. [English summary, The Importance of Lysimeter Investigations for Hydrographic Surveys, pp. [290]-291; French summary pp. [319]-320.]

(50) HAMILTON, E. L.
1954. RAINFALL SAMPLING ON RUGGED TERRAIN. U. S. Dept. Agr. Tech. Bul. 1096, 41 pp., illus.

(51) HAOUET, T.
1946. L'EVAPORATION DE L'EAU PAR LA SURFACE DU SOL. (DONNEES DES CASES LYSIMETRIQUES.) Ann. du Serv. Bot. et Agron. [Tunis] 19: [243]-259.

(52) HARROLD, L. L.
1946. SOIL WATER. Ohio Engin. Expt. Sta., Engin. Expt. Sta. News 18 (2): 19-23, illus.

(53) ———
1947. COMPARISON OF LYSIMETER RUNOFF, INFILTRATION AND PERCOLATION TO STREAM FLOW Amer. Geophys. Union Trans. 28: 438-442, illus. [Processed.]

(54) ———
1954. AVAILABLE MOISTURE FOR CROPS. Agr. Engin. 35: 99-101, illus.

(55) ———
1954. WANTED: FACTUAL DATA FOR EVALUATING THE EFFECT OF WATER CONSERVATION PROGRAMS ON THE LAND. Jour. Soil and Water Conserv. 9: 128-131, illus.

(56) ———
1955. EVAPOTRANSPIRATION RATES FOR VARIOUS CROPS. Agr. Engin. 36: 669-672, illus.

(57) HARROLD, L. L. and DREIBELBIS, F. R.
1945. AN ACCOUNTING OF THE DAILY ACCRETION, DEPLETION, AND STORAGE OF SOIL-WATER AS DETERMINED BY WEIGHING MONOLITH LYSIMETERS. Amer. Geophys. Union Trans. 26: 283-297, illus. [Processed.] (Includes discussion, pp. 292-297. See also discussion of the article: Amer. Geophys. Union Trans. 27: 288-289, 1946. [Processed.])

(58) ——— and DREIBELBIS, F. R.
1953. WATER USE BY CROPS AS DETERMINED BY WEIGHING MONOLITH LYSIMETERS. Soil Sci. Soc. Amer. Proc. 17: 70-74, illus.

(59) ——— and YODER, R. E.
1953. WATER MUST BE IN ABUNDANT SUPPLY TO PRODUCE CROPS. Ohio Farm and Home Res. 38: 45-46, illus.

(60) HESSE, W.
1954. MESSUNG DER PFLANZENTRANSPIRATION MIT KLEINLYSIMETERN. Ztschr. f. Ackerbau u. Pflanzenbau. 98: [107]-118, illus. [MEASUREMENT OF THE TRANSPIRATION OF PLANTS BY MEANS OF SMALL LYSIMETERS. English title and abstract in Commw. Bur. Soil Sci., Soils and Fert. 17: 515. 1954.]

(61) HOOGHOUDT, S. B.
1952. ENKELE OPMERKINGEN OVER DE BEPALING VAN DE GRONDWATERBERGING EN OVER HET GEBRUIK VAN LYSIMETERS IN VERBAND MET DE VOORGENOMEN ONDERZOEKINGEN IN DE ROTTEGATSPOLDER. Nederlandse Cent. Organ. v. Toegepast-Natuurw. Onderzoek, Commis. v. Hydrol. Verslag. Tech. Bijeenk. (1946-50) 1/6: [20]-30. [English summary, Some Remarks on the Determination of Groundwater Accommodation and on the Use of Lysimeters in Relation to the Intended Investigations in the Rottegatspolder, pp. 281-283; French summary pp. 309-311.]

(62) Howell, W. E.
1953. SOME MEASUREMENTS OF ABLATION, MELTING, AND SOLAR ABSORPTION ON A GLACIER IN PERU. Amer. Geophys. Union Trans. 34: 883–888, illus. [Processed.]
(63) Joffe, J. S.
1940. LYSIMETER STUDIES: IV. MOVEMENT OF ANIONS THROUGH THE PROFILE OF A GRAY-BROWN PODZOLIC SOIL. Soil Sci. 50: 57–63, illus.
(64) ———
[1941.] LYSIMETER STUDIES: THE TRANSLOCATION OF CATIONS IN THE PROFILE OF A GRAY-BROWN PODZOLIC SOIL. Soil Sci. Soc. Amer. Proc. (1940) 5: 187–190.
(65) Jolivet, E., and Helias, M.
1953. MINÉRALISATION DE L'AZOTE ORGANIQUE DANS UN SOL DE BRETAGNE APRÈS DIX ANNÉS DE DIFFÉRENTS TRAITEMENTS. [Paris] Acad. des. Sci. Compt. Rend. 237: 528–530.
(66) Kalweit, H.
1953. LYSIMETERBEOBACHTUNGEN ALS GRUNDLAGE ZUR BERECHNUNG DES WASSERHAUSHALTES. Ztschr. f. Met. 7: 35–42.
(67) Kardos, L. T.
1948. LYSIMETER STUDIES WITH CULTIVATED AND VIRGIN SOILS UNDER SUB-HUMID RAINFALL CONDITIONS. Soil Sci. 65: 367–381, illus.
(68) Karraker, P. E., Bortner, C. E., and Fergus, E. N.
1950. NITROGEN BALANCE IN LYSIMETERS AS AFFECTED BY GROWING KENTUCKY BLUEGRASS AND CERTAIN LEGUMES SEPARATELY AND TOGETHER. Ky. Agr. Expt. Sta. Bul. 557, 16 pp., illus.
(69) Kilmer, V. J., Hays, O. E., and Muckenhirn, R. J.
1944. PLANT NUTRIENT AND WATER LOSSES FROM FAYETTE SILT LOAM AS MEASURED BY MONOLITH LYSIMETERS. Amer. Soc. Agron. Jour. 36: 249–263, illus.
(70) Kohnke, H., Dreibelbis, F. R., and Davidson, J. M.
1940. A SURVEY AND DISCUSSION OF LYSIMETERS AND A BIBLIOGRAPHY ON THEIR CONSTRUCTION AND PERFORMANCE. U. S. Dept. Agr. Misc. Pub. 372, 68 pp., illus.
(71) Kupper, A., and others.
1953. MOVIMENTO DE IONS NO_3, NH_4, K E PO_4 EM SOLOS MASSAPÉ, ROXA MISTURADA E ARENITO BAURU. São Paulo, Brazil (State), Inst. Agron., Campinas, Bol. 34. (Abs. in Commw. Bur. Soil Sci., Soils and Fert. 17: 480–481. 1954.)
(72) Lee, L. S.
1952. A LYSIMETRICAL STUDY ON FIVE KINDS OF SUGARCANE SOILS IN TAIWAN. Soils and Fert. in Taiwan 1952: 54–55. [Processed.]
(73) Lowdermilk, W. C., and Sundling, H. L.
1940. EROSION PAVEMENT, ITS FORMATION AND SIGNIFICANCE. Amer. Geophys. Union Trans. 31: 96–100, illus. [Processed.]
(74) Lunt, H. A.
1941. FOREST LYSIMETER STUDIES UNDER HARDWOODS. Conn. (State) Agr. Expt. Sta. Bul. 449, pp. [515]–572, illus. [Processed.]
(75) MacIntire, W. H., and Shaw, W. M.
[1940.] CHEMISTRY: SOILS AND FERTILIZERS. Tenn. Agr. Expt. Sta. Ann. Rpt. (1939) 52: 32–40.
(76) ——— Shaw, W. M., and Robinson, B.
1941. INFLUENCE OF LIMESTONE AND DOLOMITE UPON SULFATE RETENTION FROM ANNUAL ADDITIONS OF POTASSIUM SULFATE. Soil Sci. 51: 73–84.
(77) ——— Shaw, W. M., and Robinson, B.
1950. EFFECTS OF AUTOCLAVINGS UPON THE 10-YEAR OUTGO OF NUTRIENTS FROM CUMBERLAND SILT LOAM. Soil Sci. 69: 185–191.
(78) ——— Shaw, W. M., and Robinson, B.
1955. BEHAVIOR OF INCORPORATIONS OF POTASSIUM AND CALCIUM FLUORIDES IN A 6-YEAR LYSIMETER STUDY. Jour. Agr. and Food Chem. 3: 772–777, illus.
(79) MacIntire, W. H., Shaw, W. M., Robinson, B., and Veal, C.
1954. DIFFERENTIAL FIXATION OF POTASSIUM FROM INCORPORATIONS OF METAPHOSPHATE AND SULFATE IN TWO SOILS. Jour. Agr. and Food. Chem. 2: 85–91, illus.
(80) ——— Shaw, W. M., and Young, J. B.
1953. MAGNESIC MINERALS AND SOILS. A 4-YEAR LYSIMETER STUDY OF THEIR INTERREACTIVITIES. Jour. Agr. and Food Chem. 1: 56–61, illus.

(81) MacIntire, W. H., Shaw, W. M., Young, J. B., and Robinson, B.
1936. THE EFFECTS OF 12-YEAR RESIDUES OF LIME AND MAGNESIA UPON THE OUTGO OF SUBSEQUENT ADDITIONS OF POTASH. Amer. Soc. Agron. Jour. 28: 202–215, illus.

(82) ——— and Sterges, A. J.
1952. QUENCHED CALCIUM SILICATE SLAG AND LIMESTONE INCORPORATIONS IN TWO TENNESSEE SOILS—A 10-YEAR LYSIMETER STUDY. (Abstract) Soil Sci. Soc. Amer. Proc. 16: 310.

(83) ——— and Sterges, A. J.
1953. PHOSPHATE FURNACE SLAG VS. LIMESTONE. A 10-YEAR LYSIMETER STUDY OF SOIL LIMING. Jour. Agr. and Food Chem. 1: 370–378, illus.

(84) ——— Sterges, A. J., and Shaw, W. M.
1955. FATE AND EFFECTS OF HYDROFLUORIC ACID ADDED TO FOUR TENNESSEE SOILS IN A 4-YEAR LYSIMETER STUDY. Jour. Agr. and Food Chem. 3: 777–782, illus.

(85) ——— Winterberg, S. H., Clements, L. B., and others.
1951. EFFECT OF FLUORINE CARRIERS ON CROPS AND DRAINAGE WATERS. Indus. and Engin. Chem. 43: 1797–1799.

(86) MacIntire, W. H., Young, J. B., Shaw, W. M., and Robinson, B.
1952. NITROGEN RECOVERIES FROM APPLICATIONS OF AMMONIUM CHLORIDE, PHOSPHATE, AND SULFATE AND OUTGO OF COMPLEMENTARY IONS IN RAINWATER LEACHINGS THROUGH A SIX-FOOT SOIL-SUBSOIL COLUMN. Soil Sci. Soc. Amer. Proc. 16: 301–306, illus.

(87) Makkink, G. F.
[1954.] DE EVAPOTRANSPIRATIE VAN GRASLAND IN 1953. Wageningen Cent. Inst. v. Landbouwk. Onderzoek, Verslag over 1953: 50–54, illus. [English summary, Water Consumption of Grassland in 1953, p. 54.]

(88) ———
1954. DE MIDZOMERDEPRESSIE BIJ GRASLAND ALS GEVOLG VAN WATERTEKORT. Landbouwk. Tijdschr. [Wageningen] 66: 17–26, illus. [English summary. The Midsummer Growth Depression in Grassland Due to Shortage of Water, p. 25.]

(89) Martin, W. P., and Rich, L. R.
1949. PRELIMINARY HYDROLOGIC RESULTS, 1935–48, "BASE ROCK" UNDISTURBED SOIL LYSIMETERS IN THE GRASSLAND TYPE, ARIZONA. Soil Sci. Soc. Amer. Proc. (1948) 13: 561–567, illus.

(90) Maschhaupt, J. G.
1941. LYSIMETER-ONDERZOEKINGEN AAN HET RIJKSLANDBOUWPROEFSTATION TE GRONINGEN EN ELDERS. II. DE SCHEIKUNDIGE SAMENSTELLING VAN HET DRAINWATER. [Netherlands] Dir. van den Landbouw., Verslag. van Landbouwk. Onderzoek. No. 47 (A), pt. 4, pp. 165–528, illus. [English summary, Lysimeter Investigations at Groningen and Elsewhere. Part II. The Chemical Composition of the Drainage Water, pp. 480–504.]

(91) Maschhaupt, J. G.
1948. LYSIMETERONDERZOEKINGEN TE GRONINGEN III. REGENVAL, DRAINAGE EN VERDAMPING 1918–1946. [Netherlands] Dir van den Landbouw., Verslag. van Landbouwk. Onderzoek. No. 55, pt. 6, 40 pp. illus. [English summary (title on cover), Lysimeter Investigations at Groningen III. Rainfall, Drainage and Evaporation 1918–1946, pp. 29–31.]

(92) Mooers, C. A., Washko, J. B., and Young, J. B.
1948. EFFECTS OF WHEAT STRAW, LESPEDEZA SERVICEA HAY, AND FARMYARD MANURE, AS SOIL MULCHES, ON THE CONSERVATION OF MOISTURE AND THE PRODUCTION OF NITRATES. Soil Sci. 66: 307–315.

(93) ——— Washko, J. B., and Young, J. B.
1948. EFFECT OF STRAW MULCH ON RECOVERY OF NITROGEN FROM NITRATE OF SODA AND AMMONIUM SULFATE APPLIED AS TOP-DRESSING. Soil Sci. 66: 399–400.

(94) Natermann, E.
[1952.] LYSIMETER UND WILDSCHE WAAGE. Wasserwirtschaft (formerly Deut. Wasserwirtsch.), sonderheft Sept. 1951: 10–14, illus. (Wasserwirtschaft reports meetings of the water conferences; this issue is report of meeting Sept. 19–20, 1951, in Hamburg.)

(95) Neller, J. R., and Forsee, W. T., Jr.
1942. A LYSIMETER FOR ORGANIC SOILS. Amer. Soc. Agron. Jour. 34: 345–352, illus.

(96) NIEVELT, B. F. VAN.
1952. LYSIMETERONDERZOEK IN VERBAND MET DE DRINKWATERVOORZIENING. Nederlandse Cent. Organ. v. Toegepast-Natuurw. Onderzoek, Commis. v. Hydrol. Verslag. Tech. Bijeenk. (1946–50) 1/6: [137]–140. [English summary, Investigations with the Lysimeter Related to the Drinking Water Supply, p. [290]; French summary p. [319].]

(97) ØDELIEN, M., and UHLEN, G.
1952. LYSIMETERFORSØK PÅ ÅS. Norges Landbr. Høgskole Meld. 32: 111–149, illus. [In Danish; English summary pp. 145–147. LYSIMETER EXPERIMENTS AT ÅS; English title and abstract in Commw. Bur. Soil Sci., Soils and Fert. 16: 374. 1953.]

(98) ——— and VIDME, T.
1945. LYSIMETERFORSØK PÅ ÅS, 1938–43. Norges Landbr. Høgskole Meld. 25: [273]–362, illus. [In Danish; English summary pp. 350–356. LYSIMETER EXPERIMENTS AT ÅS, 1938–43; English title and abstract in Imp. Bur. Soil Sci., Soils and Fert. 9: 104. 1946.]

(99) PFAFF, C.
1949. LYSIMETER-VERSUCHE. Ztschr. f. Pflanzenernähr., Düngung, Bodenk. 48: 93–118. [LYSIMETER STUDIES. English title and abstract in Commw. Bur. Soil Sci., Soils and Fert. 13: 348. 1950.]

(100) ———
1953. ÜBER NÄHRSTOFFAUSWASCHUNG BEI LEGUMINOSEN-GRÜNDÜNGUNG. Landw. Forsch. 5: 163–167. [LEACHING OF NUTRIENTS AND GREEN-MANURING WITH LEGUMES. English title and abstract in Commw. Bur. Soil Sci., Soils and Fert. 17: 234. 1954.]

(101) ——— and FRIEDRICH, W.
1954. DIE WASSERBILANZ DES BEWACHSENEN BODENS NACH LYSIMETER-VERSUCHEN. Wasser u. Boden 6: 281–287, illus.

(102) PLICE, M. J.
1945. LYSIMETER STUDIES IN OKLAHOMA. Okla. Acad. Sci. Proc. (1944) 25: 39–42.

(103) POST, F. A., and DREIBELBIS, F. R.
1943. SOME INFLUENCES OF FROST PENETRATION AND MICROCLIMATE ON THE WATER RELATIONSHIPS OF WOODLAND, PASTURE, AND CULTIVATED SOILS. Soil Sci. Soc. Amer. Proc. (1942) 7: 95–104, illus.

(104) RICHARDS, L. A., NEAL, O. R., and RUSSELL, M. B.
[1940.] OBSERVATIONS ON MOISTURE CONDITIONS IN LYSIMETERS. II. Soil Sci. Soc. Amer. Proc. (1939) 4: 55–59, illus.

(105) ROLLER, E. M., and BOWEN, A. B.
1944. SOIL AND FERTILIZER INVESTIGATIONS. LYSIMETER STUDIES. S. C. Agr. Expt. Sta. Ann. Rpt. (1942–43) 56: 115–124, illus.

(106) ROSEAU, H.
[1948.] SUR LA CIRCULATION DE L'EAU DANS LE SOL. OBSERVATIONS EN CASES LYSIMÉTRIQUES. [Internatl.] Conf. de Pédol. Méditerr., Alger-Montpellier, May 1–20, Compt. Rend. 1947: [389]–404, illus.

(107) ———
1953. SENS DU MOUVEMENT DE L'EAU DANS LE SOL SOUS L'INFLUENCE DE LA TEMPÉRATURE. [France] Centre Natl. de la Rech. Sci., Colloques Internationaux 35, pp. [347]–352, illus. [Includes discussion, pp. 351–352. English summary p. 347.]

(108) ——— and BATS, J.
[1952.] OBSERVATIONS SUR LA SOLUTION DU SOL DITE D'ÉTÉ, EN CASES LYSIMÉTRIQUES. Trans. Internatl. Soc. Soil Sci. Commis. 2 and 4, Dublin, July 1952, v. 2, pp. 248–252. [English summary p. 252.]

(109) SCHARRER, K., and KÜHN, H.
1952. SICKERVERSUCHE ZUR ERMITTLUNG DER AUSWASCHUNG UND TIEFENWIRKUNG VERSCHIEDENER PHOSPHORSÄUREDÜNGEMITTEL ALLEIN UND BEI ANWESENHEIT VON STALLDÜNGER. Ztschr. f. Pflanzenernähr. Düngung, Bodenk. 58: 146–162. [LYSIMETER EXPERIMENTS FOR DETERMINING THE LEACHING AND DEPTH OF EFFECT OF DIFFERENT PHOSPHORUS FERTILIZERS ALONE AND WITH FARMYARD MANURE. English title and abstract in Commw. Bur. Soil Sci., Soils and Fert. 16: 130. 1953.]

(110) SCHARRER, K., KÜHN, H., and LÜTTMER, J.
1955. ÜBER DIE AUSWASCHUNG DES BORS IM BODEN. Landw. Forsch. 7: 89-105.
(111) SHAW, W. M., MACINTIRE, W. H., and HILL, H. H.
1949. THE CONSERVATION OF CALCIUM AND MAGNESIUM FROM INPUTS OF BURNT LIME, LIMESTONE, DOLOMITE, AND DICALCIUM SILICATE, AS INFLUENCED BY RATE AND FREQUENCY OF LIMING AND BY ZONE OF INCORPORATION. Tenn. Agr. Expt. Sta. Bul. 212, 95 pp., illus.
(112) SHAWARBI, M. Y.
[1950.] THE STATUS OF PHOSPHATES IN SALINE AND ALKALINE SOILS WITH SPECIAL REFERENCE TO EGYPTIAN SOILS. Trans. 4th Internatl. Cong. Soil Sci., Amsterdam, July 24-Aug. 1, 1950, 2: 262-265.
(113) SMITH, C. A.
1953. NOTE ON THE SETTING UP OF A BATTERY OF SMALL LYSIMETERS. New Zeal. Jour. Sci. and Technol., Sect. A, 35: 394, illus.
(114) SMITH, H. V.
1944. A LYSIMETER STUDY OF THE NITROGEN BALANCE IN IRRIGATED ARID SOILS. Ariz. Agr. Expt. Sta. Tech. Bul. 102, pp. 259-308, illus.
(115) STACKHOUSE, J. M., and YOUKER, R. E.
1954. EVALUATION OF THE ACCURACY OF FIBERGLAS-GYPSUM BLOCKS FOR MEASURING SOIL MOISTURE CHANGES. Agron. Jour. 46: 405-407, illus.
(116) STAUFFER, R. S.
1942. RUNOFF, PERCOLATE, AND LEACHING LOSSES FROM SOME ILLINOIS SOILS. Amer. Soc. Agron. Jour. 34: 830-835.
(117) ——— and RUST, R. H.
1954. LEACHING LOSSES, RUNOFF, AND PERCOLATE FROM EIGHT ILLINOIS SOILS. Agron. Jour. 46: 207-211, illus.
(118) SUNDARA RAO, W. V. B., DESAI, S. V., and TEJWANI, K. G.
1953. A LYSIMETER STUDY OF CROP ROTATIONS. II. THE QUALITY AND CHEMICAL COMPOSITION OF CROPS. Indian Jour. Agr. Sci. 23: 255-268.
(119) SUOMI, V. E., FRANSSILA, M., and ISLITZER, N. F.
1954. AN IMPROVED NET-RADIATION INSTRUMENT. Jour. Met. 11: 276-282, illus.
(120) THERON, J. J.
[n. d.] LYSIMETER EXPERIMENTS. Union So. Africa Dept. Agr. Sci. Bul. 288, 41 pp., illus.
(121) TURC, L.
1954. INTER-RELATIONS OF RAINFALL, EVAPORATION, AND RUN OFF. (Abstract) Sols Africains [France] 3: 139-172 (incl. of French portion), illus. (French presentation begins p. 138.)
(122) ———
1955. LE BILAN D'EAU DES SOLS: RELATIONS ENTRE LES PRÉCIPITATIONS L'ÉVAPORATION ET L'ÉCOULEMENT. [France] Min. de l'Agr., Inst. Natl. de la Rech. Agron., Ann., Ser. A., Ann. Agron. 6: 5-31, illus.
(123) UNITED STATES SOIL CONSERVATION SERVICE.
1941. HYDROLOGIC DATA: NORTH APPALACHIAN EXPERIMENTAL WATERSHED, COSHOCTON, OHIO, 1939. U. S. Soil Conserv. Serv. Hydrologic Bul. 1, 193 pp., illus.
(124) ———
1942. HYDROLOGIC DATA: NORTH APPALACHIAN EXPERIMENTAL WATERSHED, COSHOCTON, OHIO, 1940. U. S. Soil Conserv. Serv. Hydrologic Bul. 4, 338 pp., illus.
(125) VAN'T WOUDT, B. D.
1954. ON FACTORS GOVERNING SUBSURFACE STORM FLOW IN VOLCANIC ASH SOILS, NEW ZEALAND. Amer. Geophys. Union Trans. 35: 136-144, illus. [Processed.]
(126) ———
1955. ON A HILLSIDE MOISTURE GRADIENT IN VOLCANIC ASH SOIL, NEW ZEALAND. Amer. Geophys. Union Trans. 36: 419-424, illus. [Processed.]

(127) VISSER, W. C.
1952. CRITISCHE VERGELIJKING TUSSEN HET GEBRUIK VAN DE LYSIMETER EN VAN ANDERE BEPALINGSMOGELIJKHEDEN VAN DE WATERBALANS. Nederlandse Cent. Organ. v. Toegepast-Natuurw. Onderzoek, Commis. v. Hydrol. Verslag. Tech. Bijeenk. (1946–50) 1/6: [163]-171. [English summary, Critical Comparison Between the Use of the Lysimeter and of Other Possibilities to Determine the Water Balance, pp. 292–293; French summary pp. 321–322.]

(128) VOLK, G. M.
1955. UREA NITROGEN AND SANDY SOILS. Agr. Chem. 10 (9): 41–42, 133, 135, 137.

(129) ———
1956. EFFICIENCY OF VARIOUS NITROGEN SOURCES FOR PASTURE GRASSES IN LARGE LYSIMETERS OF LAKELAND FINE SAND. Soil Sci. Soc. Amer. Proc. 20: 41–45, illus.

(130) VOLK, G. M. and BELL, C. E.
1945. SOME MAJOR FACTORS IN THE LEACHING OF CALCIUM, POTASSIUM, SULFUR AND NITROGEN FROM SANDY SOILS. A LYSIMETER STUDY. Fla. Agr. Expt. Sta. Bul. 416, 23 pp., illus.

(131) ——— and BELL, C. E.
1948. EFFECT OF ANION BALANCE ON THE LEACHING OF IONS FROM SANDY SOILS. Soil Sci. Soc. Amer. Proc. (1947) 12: 188–190.

(132) WALLIHAN, E. F.
1940. AN IMPROVEMENT IN LYSIMETER DESIGN. Amer. Soc. Agron. Jour. 32: 395–404, illus.

(133) WINNIK, M.
[1950.] SOME EFFECTS OF P AND K DEFICIENCIES ON ORANGE TREE GROWTH, COMPOSITION AND FRUIT QUALITY. Trans. 4th Internatl. Cong. Soil Sci., Amsterdam, July 24–Aug. 1, 1950, 1: 240–242.

(134) YOUKER, R. E., and DREIBELBIS, F. R.
1951. AN IMPROVED SOIL-MOISTURE MEASURING UNIT FOR HYDROLOGIC STUDIES. Amer. Geophys. Union Trans. 32: 447–449, illus. [Processed.]

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APPENDIX

TABLE 34.—*Summary of farming operations on all lysimeters, 1936–55*

Year	Lysimeter battery Y101	Lysimeter battery Y102	Lysimeter battery Y103
1936	Cover: Pasture grass.	Cover: Meadow, poor	Cover: Meadow, poor.
1937	Cover: Pasture grass.	Cover: Meadow, poor; burlap, Apr. 2–Oct. 11. Seeded: Oct. 15, 4 pounds rye and 2 bushels oats per acre; no fertilizer. Manure: Oct. 29, 8 tons per acre.	Cover: Meadow, poor.
1938	Cover: Pasture grass— Red top. Canada bluegrass. Timothy. Poverty grass. Weeds.	Crop: Corn. Spaded. May 10–13. Corn planted May 27, 125 pounds of 2–12–6 fertilizer per acre. Cultivated: June 7–9, 28–29, July 11. Harvested: Sept. 23–27, crop removed. Yield: No data.	Cover: Meadow to wheat. Spaded: Late September. Seeded: October 7, 2 bushels wheat per acre, 175 pounds 2–12–6 fertilizer per acre.
1939	Cover: Pasture grass— Tame grass. Poverty grass. Weeds.	Crop: Oats to wheat. Spaded and raked: May 1–2. Oats planted: May 4, 100 pounds 0–20–0 fertilizer per acre. Oats lodged: July 13. Harvested: July 27. Yield of oats: A—43 bushels per acre. B—44 bushels per acre. C—45 bushels per acre. Spaded: Sept. 1. Raked: Sept. 9. Wheat seeded: Oct. 2, 2 bushels wheat and 5 pounds timothy per acre. 150 pounds 0–16–0 and 10 pounds 20–0–0 fertilizer per acre.	Crop: Oats to wheat. Spaded and raked: Apr. 26–27. Oats planted: May 4, 100 pounds 0–20–0 fertilizer per acre. Harvested: July 24–25. Yield of oats: No record. Spaded: Sept. 1. Raked: Sept. 9. Wheat seeded: Oct. 2, 2 bushels wheat and 5 pounds timothy per acre. 150 pounds 0–16–0 and 10 pounds 20–0–0 fertilizer per acre.

TABLE 34.—*Summary of farming operations on all lysimeters, 1936–55*—Continued

Year	Lysimeter battery Y101	Lysimeter battery Y102	Lysimeter battery Y103
1940	Cover: Pasture grass. Yield: A—0.46 ton per acre. B—0.47 ton per acre. C—0.45 ton per acre.	Crop: Wheat to meadow. Clover seeded: Mar. 15, 6 pounds red clover and 3 pounds alsike clover per acre. Wheat harvested: July 12. Yield: A: grain—31 bushels per acre. straw—1.2 tons per acre. B: grain—28 bushels per acre. straw—1.1 tons per acre. C: grain—24 bushels per acre. straw—0.9 ton per acre.	Crop: Wheat to meadow. Clover seeded: Mar. 15, 6 pounds red clover per acre and 3 pounds alsike clover per acre. Wheat harvested: July 12. Yield: A: grain—23 bushels per acre. straw—0.9 ton per acre. B: grain—33 bushels per acre. straw—1.3 tons per acre. C: grain—24 bushels per acre. straw—0.9 ton per acre. D: grain—26 bushels per acre. straw—1.0 ton per acre.
1941	Cover: Pasture grass. Poverty grass. Weeds. Clover.	Conservation practices on all lysimeters. Crop: Corn to wheat. Manured: Mar. 29, 4 tons per acre. Spaded: Mar. 29–Apr. 1. Raked and seeded: May 12, 200 pounds 2–12–6 fertilizer per acre. Cultivated: June 9, 23. Corn cut and removed: Sept. 15. Yield: A: grain—102 bushels per acre. fodder—2.5 tons per acre. B: grain—99 bushels per acre. fodder—2.6 tons per acre. C: grain—80 bushels per acre. fodder—2.4 tons per acre.	Conservation practices on A and B only. Crop: Corn to wheat. Manured: Apr. 1, 4 tons per acre. Spaded: Apr. 1–2. Raked and seeded: May 13— A and B: 200 pounds 2–12–6 fertilizer per acre. C and D: 75 pounds 2–12–6 fertilizer per acre. Cultivated: June 9, 23. Corn cut and removed: Sept. 15. Yield: A: grain—92 bushels per acre. fodder—2.0 tons per acre. B: grain—102 bushels per acre. fodder—2.3 tons per acre. C: grain—94 bushels per acre. fodder—2.5 tons per acre.

TABLE 34.—*Summary of farming operations on all lysimeters, 1936–55*—Continued

Year	Lysimeter battery Y101	Lysimeter battery Y102	Lysimeter battery Y103
		Raked and wheat seeded: Oct. 2. Seed: 2 bushels wheat, and 3 pounds timothy per acre. 300 pounds 2–12–6 fertilizer per acre. Manured: Dec. 31, 4 tons per acre.	D {grain—95 bushels per acre. fodder—2.9 tons per acre. Raked and wheat seeded: Oct 2.—2 bushels wheat and 3 pounds timothy per acre. A and B: 300 pounds 2–12–6 fertilizer per acre. C and D: 125 pounds 2–12–6 fertilizer per acre.
1942	Cover: Pasture grass— Poverty grass. Weeds. Clover.	Crop: Wheat to meadow. Clover seeded: Apr. 13, 4 pounds red clover, 6 pounds alfalfa, and 2 pounds alsike per acre, Wheat cut: June 29. Yield: A {grain—38 bushels per acre. straw—1 0 ton per acre. B {grain—30 bushels per acre. straw—0.8 ton per acre. C {grain—32 bushels per acre. straw—0.9 ton per acre. Stubble clipped: Aug. 18.	Crop: Wheat to meadow. Manured: Mar. 2, A and B only—4 tons per acre. Clover seeded: Apr. 13— A and B: 4 pounds red clover, 6 pounds alfalfa, and 2 pounds alsike per acre. C and D: 6 pounds red clover and 3 pounds alsike per acre. Wheat cut: June 30. Yield: A {grain—35 bushels per acre. straw—1.0 ton per acre. B {grain—39 bushels per acre. straw—1.2 tons per acre. C {grain—23 bushels per acre. straw—0.6 ton per acre. D {grain—30 bushels per acre. straw—0.7 ton per acre. Stubble clipped: Aug. 26, A and B only.

TABLE 34.—*Summary of farming operations on all lysimeters, 1936–55*—Continued

Year	Lysimeter battery Y101	Lysimeter battery Y102	Lysimeter battery Y103
1943	Cover: Pasture grass. Lysimeter D now in operation. A, B, and C: Poverty grass. Weeds. Clover. D: Mostly bare.	Crop: Meadow, first year. Hay cut: June 16. Hay removed: June 19. Yield: C—2.06 tons per acre, only one cutting; second growth, estimated 0.30 ton per acre.	Crop: Meadow, first year. Hay cut: June 17. Hay removed: June 19. Yield: A—1.17 tons per acre. Hay cut: Sept. 10. Yield: A—estimated 0.5 ton per acre.
1944	Cover: Pasture grass— Poverty grass. Weeds. Clover.	Crop: Meadow, second year. Limed: Apr. 25, 2.5 tons per acre. Hay cut: June 19. Hay removed: June 21. Yield: C—1.25 tons per acre, only one cutting this year; second crop poor; second growth estimated at 0.25 ton per acre. Manured: Oct. 18, 6 tons per acre.	Crop: Meadow, second year. Limed: Apr. 25, A and B only, 2.5 tons per acre. Hay cut: June 19. Hay removed: June 21. Yield: A—1.0 ton per acre. Hay cut: Aug. 25. Yield: A—estimated 0.5 ton per acre. Manured: Oct. 18, 6 tons per acre.
1945	Cover: Pasture grass— A and B: Poverty grass. Weeds. C and D: improved. Sod chopped: Apr. 12, C and D only. Seeded: Apr. 12, C and D only: 3 tons lime, 500 pounds 2–12–6 fertilizer, and 4 tons manure per acre. 4 pounds ladino clover, 4 pounds white clover, and 100 pounds blue grass per acre. Grass cut: July 25.	Crop: Corn to wheat. Spaded: Apr. 30. Corn planted: May 23. 200 pounds 2–12–6 fertilizer per acre. Cultivated: June 23, July 12. Cut and removed: Sept. 28. Yield: A {grain—54 bushels per acre. fodder—3.6 tons per acre.} B {grain—60 bushels per acre. fodder—3.7 tons per acre.} C {grain—34 bushels per acre. fodder—2.7 tons per acre.} Seedbed prepared: Oct. 18. Wheat seeded: Oct. 18, 2 bushels wheat and 6 pounds timothy per acre. 300 pounds 2–12–6 fertilizer per acre.	Crop: Corn to wheat. Spaded: Apr. 30. Corn planted: May 23— A and B: 200 pounds 2–12–6 fertilizer per acre. C and D: 75 pounds 2–12–6 fertilizer per acre. Cultivated: June 23, July 12. Cut and removed: Oct. 2. Yield: A {grain—61 bushels per acre. fodder—3.6 tons per acre.} B {grain—62 bushels per acre. fodder—3.6 tons per acre.} C {grain—48 bushels per acre. fodder—3.0 tons per acre.} D {grain—57 bushels per acre. fodder—3.5 tons per acre.}

TABLE 34.—*Summary of farming operations on all lysimeters, 1936–55*—Continued

Year	Lysimeter battery Y101	Lysimeter battery Y102	Lysimeter battery Y103
		Lime: 2 tons per acre.	Seedbed prepared: Oct. 18. Wheat seeded: Oct. 18, 2 bushels wheat and 6 pounds timothy per acre. A and B: 300 pounds 2–12–6 fertilizer per acre. C and D: 125 pounds 2–12–6 fertilizer per acre. Lime: A and B—2 tons per acre.
1946	Cover: Pasture grass— A and B: Poverty grass. Weeds. C and D: Grass. Clover. Fertilized: Sept. 4, 1946, C and D only.—400 pounds 0–20–0 fertilizer and 2 tons lime per acre. Yield: A—0.65 ton per acre. B—0.28 ton per acre. C—0.53 ton per acre. D—0.50 ton per acre.	Crop: Wheat to meadow. Manured: Jan 3, 4 tons per acre. Clover seeded: Mar. 25. 4 pounds red clover, 6 pounds alfalfa, and 2 pounds alsike per acre. Wheat cut: July 9. Yield: A—grain—40 bushels per acre. B—grain—30 bushels per acre. C {grain—38 bushels per acre. straw—1.0 ton per acre.	Crop: Wheat to meadow. Manured: Jan. 3, A and B only, 4 tons per acre. Clover seeded: Mar. 25— A and B: 4 pounds red clover, 6 pounds alfalfa, and 2 pounds alsike per acre. C and D: 6 pounds red clover and 3 pounds alsike per acre. Wheat cut: July 9. Yield: A {grain—36 bushels per acre. straw—1.0 ton per acre. B—grain—38 bushels per acre. C—grain—29 bushels per acre. D—grain—33 bushels per acre.
1947	Cover: Pasture grass— A and B: Poverty grass. Weeds. C and D: Grass. Clover. Fertilized: Apr. 18, C and D only, 500 pounds 3–12–12 per acre. Sod chopped: Apr 18, D only.	Crop: Meadow, first year. Hay cut: June 23, Aug 5. Yield (tons per acre): *June 23* *Aug. 5* A—1.47 1.18 B—1.58 1.08 C—1.65 .88 Fertilized: June 27, 200 pounds 0–12–20 per acre.	Crop: Meadow, first year. Hay cut: June 25, Aug. 11. Yield (tons per acre): *June 25* *Aug. 11* A—1.15 0.80 B—1.42 .76 C— .98 .76 D—1.03 .88 Fertilized: A and B only, 200 pounds 0–12–20 per acre in July.

TABLE 34.—*Summary of farming operations on all lysimeters, 1936–55*—Continued

Year	Lysimeter battery Y101	Lysimeter battery Y102	Lysimeter battery Y103
	Seeded: May 8, D only, 8 pounds alfalfa, 1 pound ladino clover, and 7 pounds bromegrass per acre. Grass clipped: Aug 1, clippings left on surface.		
1948	Cover: Pasture grass— A and B: Poverty grass. Weeds. C: Bluegrass. D: Bromegrass. Alfalfa. Clover. Grass clipped: May 28. Yield: A—1.4 tons per acre. B—0.4 ton per acre. C—0.5 ton per acre. D—3.4 tons per acre.	Crop: Meadow, second year Hay cut: June 25, Aug. 9. Yield: A—3.3 tons per acre. B—4.2 tons per acre C—3.1 tons per acre.	Crop: Meadow, second year. Hay cut: June 28, Aug. 11. Yield: A—3.8 tons per acre. B—3.1 tons per acre. C—1.7 tons per acre. D—2.5 tons per acre.
1949	Cover: Pasture grass— A and B: Poverty grass. Weeds. C: Bluegrass. D: Bromegrass. Alfalfa. Grass cut: June 20, Aug. 18. Yield: A—1.4 tons per acre. B—1.3 tons per acre. C—1.1 tons per acre. D—4.0 tons per acre.	Crop: Corn to wheat. Manured: Apr. 25, 6 tons per acre. Sod spaded: May 6. Corn planted: May 9. Fertilized: 300 pounds 3–12–12 per acre. Cultivated: June 2, 14, July 1. Corn picked, stalks chopped and left: Sept. 21. Yield: A—grain—151 bushels per acre. B—grain—148 bushels per acre. C: grain—151 bushels per acre.; fodder—2.75 tons per acre. Wheat seeded: Oct. 3—2 bushels wheat and 3 pounds timothy per acre. 300 pounds 3–12–12 fertilizer per acre.	Crop: Corn to wheat. Manured: Apr. 25, 6 tons per acre. Sod spaded: May 6. Corn planted: May 10— A and B: 300 pounds fertilizer 3–12–12 per acre. C and D: 100 pounds fertilizer 2–12–6 per acre. Cultivated: June 3, 14, July 1. Corn picked, stalks chopped and left: Sept 21. Yield: A: grain—148 bushels per acre.; fodder—2.55 tons per acre. B—grain—154 bushels per acre. C—grain—107 bushels per acre. D—grain—120 bushels per acre.

TABLE 34.—*Summary of farming operations on all lysimeters, 1936–55*—Continued

Year	Lysimeter battery Y101	Lysimeter battery Y102	Lysimeter battery Y103
			Wheat seeded: Oct 4—2 bushels wheat and 3 pounds timothy per acre. A and B: 300 pounds 3–12–12 fertilizer per acre. C and D: 200 pounds 2–12–6 fertilizer per acre.
1950	Cover: Pasture grass— A and B: Poverty grass. C: Bluegrass. D: Bromegrass. Alfalfa. Yield: A—0.85 ton per acre. B—0.77 ton per acre. C—1.00 ton per acre. D—3.09 tons per acre.	Crop: Wheat to meadow. Manured: Jan. 17, 6 tons per acre. Clover seeded: 3 pounds red clover, 6 pounds alfalfa, and 3 pounds timothy per acre. Wheat cut: July 7. Yield: A {grain—29 bushels per acre. straw—1.3 tons per acre. B {grain—44 bushels per acre. straw—2.0 tons per acre. C {grain—43 bushels per acre. straw—1.9 tons per acre. NOTE: Heavy stand of wheat and heavy manure resulted in poor meadow seeding. Reseeded: Aug. 4, 7 pounds alfalfa, 3 pounds red clover, and 3 pounds timothy per acre.	Crop: Wheat to meadow. Manured: Jan. 17, A and B only: 6 tons per acre. Clover seeded: A and B: 3 pounds red clover, 6 pounds alfalfa, and 3 pounds timothy per acre. C and D: 6 pounds red clover, 3 pounds alsike, and 3 pounds timothy per acre. Wheat cut: July 7. Yield: A {grain—43 bushels per acre. straw—2.0 tons per acre. B {grain—50 bushels per acre. straw—2.2 tons per acre. C {grain—30 bushels per acre. straw—1.4 tons per acre. D {grain—34 bushels per acre. straw—1.1 tons per acre. NOTE: Heavy stand of wheat and heavy manure resulted in poor meadow seeding on A and B.

TABLE 34.—*Summary of farming operations on all lysimeters, 1936–55*—Continued

Year	Lysimeter battery Y101	Lysimeter battery Y102	Lysimeter battery Y103
			Reseeded: Aug. 4, A and B: 7 pounds alfalfa, 3 pounds red clover, and 3 pounds timothy per acre.
1951	Cover: Pasture grass— A and B: Poverty grass. C: Bluegrass. D: Bromegrass. Alfalfa. Grass cut: June 8, Aug. 13. Yield (tons per acre): *June 8* *Aug. 13* A--- 0.78 0.30 B--- .78 .33 C--- 1.70 .40 D--- 2.11 1.00 Fertilized: Mar. 6, C only: 1,000 pounds 8–0–0 per acre.	Crop: Meadow, first year. Hay cut: June 7, Aug. 8. Yield (tons per acre): *June 7* *Aug. 8* A-- 1.69 1.83 B-- 1.17 1.84 C-- 1.11 1.59 Fertilized: Aug. 22, 150 pounds 0–10–30 per acre.	Crop: Meadow, first year. Hay cut: June 8, Aug. 8. Yield (tons per acre): *June 8* *Aug. 8* A--- 1.12 1.15 B--- .62 1.26 C--- .97 1.12 D--- 1.34 1.30 Fertilized: Aug. 22, A and B only: 150 pounds 0–10–30 per acre. Alfalfa eradicated: Sept. 27, C and D.
1952	Cover: Pasture grass— A and B: Poverty grass. C: Bluegrass. D: Bromegrass. Alfalfa. Grass cut: June 2, July 14. Yield (tons per acre): *June 2* *July 14* A--- 0.25 0.06 B--- .20 .12 C--- .72 .07 D--- 2.14 .83 Fertilized: Feb. 5, C and D only: 500 pounds 3–12–12 per acre.	Crop: Meadow, second year. Hay cut: June 4, July 14. Yield (tons per acre): *June 4* *July 14* A-- 2.44 1.94 B-- 2.06 1.72 C-- 1.62 1.02 Limed: Aug. 15, 1 ton per acre.	Crop: Meadow, second year. Hay cut: June 4, July 14. Yield (tons per acre): *June 4* *July 14* A--- 2.44 0.92 B--- 2.36 .80 C--- 1.50 .32 D-- 1.16 .78 Limed: Aug. 22, A and B only: 1 ton per acre.

TABLE 34.—*Summary of farming operations on all lysimeters, 1936–55*—Continued

Year	Lysimeter battery Y101	Lysimeter battery Y102	Lysimeter battery Y103
1953	Cover: Pasture grass— A and B: Poverty grass. C: Bluegrass. D: Bromegrass. Alfalfa. Grass cut: June 17, Aug. 11. Yield (tons per acre): *June 17* *Aug. 11* A— 0.26 0.15 B— .30 .36 C— .88 .44 D— 1.86 .90 Fertilized: Mar. 3, C only: 400 pounds 8-8-8 per acre.	Crop: Corn to wheat. Manured: Apr. 10, 6 tons per acre. Sod spaded: May 1. Corn planted: May 13, 300 pounds 3-12-12 per acre. Cultivated: June 15 and 30. Fertilized: July 7, B and C: 80 pounds nitrogen per acre; July. Irrigated: B and C—July 14, 2.932 inches; Aug. 25, 2.896 inches. Corn picked: Sept. 21. Yield: A: grain—160 bushels per acre. fodder—2.6 tons per acre. B: grain—177 bushels per acre. fodder—3.5 tons per acre. C: grain—196 bushels per acre. fodder—3.1 tons per acre. Soil and stalks chopped: Oct. 1. Wheat seeded: Oct. 1, 2 bushels wheat and 3 pounds timothy per acre. 300 pounds 3-12-12 fertilizer per acre. Wheat irrigated: Oct. 12, 0.576 inch; Oct. 21, 1.725 inches.	Crop: Corn to wheat. Manured: Apr. 10, 6 tons per acre. Sod spaded: May 1. Corn planted: May 13. Fertilized: A and B: 300 pounds 3-12-12 per acre. C and D: 100 pounds 3-12-12 per acre. Cultivated: June 15. Corn picked: Sept. 21. Yield: A: grain—143 bushels per acre. fodder—3 tons per acre. B: grain—146 bushels per acre. fodder—2.2 tons per acre. C: grain—109 bushels per acre. fodder—1.6 tons per acre. D: grain—117 bushels per acre. fodder—1.8 tons per acre. Soil and stalks chopped: Oct. 2. Wheat seeded: Oct. 2, 2 bushels wheat and 3 pounds timothy per acre. A and B: 300 pounds 3-12-12 per acre. C and D: 200 pounds 2-12-6 per acre.

TABLE 34.—*Summary of farming operations on all lysimeters, 1936–55*—Continued

Year	Lysimeter battery Y101	Lysimeter battery Y102	Lysimeter battery Y103
1954	Cover: Pasture grass. A and B: Poverty grass. C: Bluegrass. D: Bromegrass. Alfalfa. Grass cut: June 15, Aug. 12. Yield (tons per acre): *June 15* *Aug. 12* A— 0.17 0.18 B— .14 .11 C— .33 .12 D— 1.39 .23	Crop: Wheat to meadow. Measured: Feb. 9, 4 tons per acre. Seeded: Mar. 16, 6 pounds alfalfa, 3 pounds red clover, and 3 pounds timothy per acre. Wheat cut: July 13. Yield: A {grain—49.6 bushels per acre. straw—1.4 tons per acre. B {grain—53.8 bushels per acre. straw—1.4 tons per acre. C {grain—53.8 bushels per acre. straw—1.4 tons per acre. NOTE: Heavy wheat stand resulted in poor meadow seeding. Reseeded: July 16, 6 pounds alfalfa, 3 pounds red clover, and 3 pounds timothy per acre. Mulched (with straw): July 16. Irrigated: July 16, 1.13 inches. Stubble clipped: Sept. 1. Irrigated: Sept. 13, B and C only: 1.65 inches.	Crop: Wheat to meadow. Manured: Feb. 9, 4 tons per acre. Seeded: Mar. 16— A and B: 6 pounds alfalfa, 3 pounds red clover, and 3 pounds timothy per acre. C and D: 6 pounds red clover, 3 pounds alsike, and 3 pounds timothy per acre. Wheat cut: July 13. Yield: A {grain—47.9 bushels per acre. straw—1.3 tons per acre. B {grain—47.0 bushels per acre. straw—1.3 tons per acre. C {grain—31.7 bushels per acre. straw—0.9 ton per acre. D {grain—23.6 bushels per acre. straw—0.7 ton per acre. Stubble clipped: Sept. 1.
1955	Cover: Pasture grass. A and B: Poverty grass. C: Bluegrass. D: Bromegrass. Alfalfa. Grass cut: June 3, July 22. Yield (tons per acre): *June 3* *July 22* A— 0.37 0.12 B— .28 .13 C— .68 .06 D— 1.46 .72 Irrigated: June 6, 3.61 inches.	Crop: Meadow, first year. Hay cut: June 6, July 22. Yield (tons per acre): *June 6* *July 22* A— 3.58 1.38 B— 3.84 2.03 C— 3.87 2.10 Irrigated: B and C only—May 18, 2.25 inches; June 29, 3.07 inches. Fertilized: Aug. 10, 200 pounds 0–10–30 per acre.	Crop: Meadow, first year. Hay cut: June 6, July 22. Yield (tons per acre): *June 6* *July 22* A— 3.35 1.08 B— 3.35 1.06 C— 2.00 .67 D— 2.35 .94 Fertilized: Aug. 9, 200 pounds 0–10–30 per acre.

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