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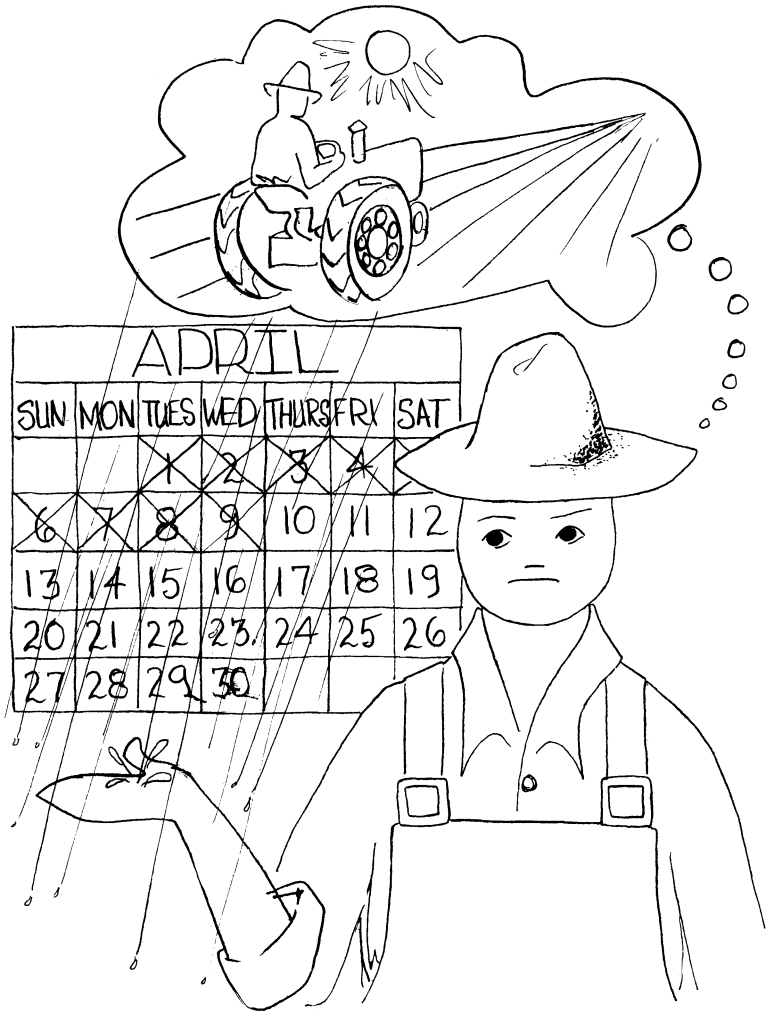
THE EFFECT OF WEATHER ON THE DAYS AVAILABLE TO DO SELECTED CROP OPERATIONS

Central Ohio, 1938-1957



August, 1960

Department of Agricultural Economics and Rural Sociology
The Ohio State University.

THE EFFECT OF WEATHER ON THE DAYS AVAILABLE TO DO SELECTED CROP OPERATIONS

Central Ohio, 1938-1957

by

John H. Sitterley

and

Richard Bere

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Preface

In organizing a farm business we are confronted with the problem of determining the amount of labor and equipment needed to do the job. This study provides information on the restrictions exerted by weather on time in which field operations may be performed.

The study revealed several areas in which little empirical data exists. The first of these is the influence of the various aspects of climate, such as rainfall, temperature, sunshine, wind velocity, and humidity under different soil and drainage conditions on the duration of a work stoppage due to unfavorable weather. A second area of inadequate information is the field drying time needed for grain and meadow crops by different systems of harvesting. As data in these areas becomes available, assumptions made in the study can be replaced and the climatic limitations on time available more accurately appraised.

THE EFFECT OF WEATHER ON THE DAYS AVAILABLE TO DO SELECTED CROP OPERATIONS[1/]
Central Ohio, 1938-1957

Introduction

One of the uncertainties of farming which has persistently plagued the farmer is that of weather. Weather and drainage are two major factors that determine the amount of time available throughout the year for field operations. In some years little or no time is available for performing one or several field operations under favorable conditions. In other years, favorable weather permits abundant time for completing field operations without working excessively long hours, or working when conditions are not satisfactory.

The wide variation in time available from year to year creates a major management problem in supplying the farm with machinery, power, and labor. Many farm operators invest large amounts of capital in large machinery and power units to be able to complete their operations under the most adverse weather. Consequently, they are over equipped in the years with average or better weather conditions. To maximize the returns over a period of years, it is essential that a farmer balance the cost of being over-equipped in favorable years with the increased returns arising from having adequate capacity to do the job in the least favorable years. To do this, it is necessary to know the time available for each major field operation and the frequency and extent of the restrictions on days available.

[1/] The authors of this report wish to express their appreciation to the many individuals who gave generously of their time and who made many valuable suggestions. They are especially indebted to Dr. R. H. Baker and Dr. E. T. Shaudys of the Department of Agricultural Economics, to Virgil Overholt of the Department of Agricultural Engineering, and to T. W. Pierce, State Climatologist.

An attempt has been made in this study to secure information on the restrictions imposed by weather on time available for the major field operations and to present it in such a form that it can be used by farmers in planning their equipment and labor.

Procedure

Very few detailed records have been kept by farmers of the days when weather and soil conditions were favorable for the performance of particular farm operations. In the absence of records of this type, detailed records kept by the Weather Bureau on daily climatic conditions together with a set of assumptions based on available information and observation on rate of water removal by drainage, evaporation, and transpiration were used in estimating the days favorable for particular farm operations.

Detailed information is available at major weather stations on temperature, humidity for different hours, rainfall by 6-hour periods, wind velocity, per cent of possible sunshine, etc. Information of this type was secured from the Columbus Weather Station for the 20-year period, 1938-1957. A check was then made to determine whether this period represented a true cross section of Columbus climatic conditions. To do this, a comparison with a 52-year period, 1906-1957, was made. Both average monthly rainfall and the number of days with .01 inch or more of rain were almost identical. However, it was found that slightly greater extremes in monthly rainfall and in days with .01 inch or more occurred in the 52-year period than appeared in the 20-year period. The difference was not considered sufficient to alter the conclusions in the study in light of the assumptions that were made regarding the rate of drying after a rainfall. (See Table I in the Appendix).

Two procedures were developed to determine the days suitable for performing selected farm operations. Soil operations such as plowing, fitting and seeding necessitated a different procedure than harvesting operations. In the former, the amount of moisture in the soil and the rate of drying of the soil were major concerns. Consequently, drainage and the removal of soil moisture by evaporation and transpiration through plants had to be considered.

In analyzing days suitable for harvesting operations, the drying rate of the crop to be harvested was of first importance, except in unusually wet periods such as occurred in the summer of 1958 when excess soil moisture limited the movement of power and equipment. In determining days available for harvesting, the presence or absence of rainfall, the temperature, humidity, sunshine, and wind velocity were taken into account. Only when there was excessive rainfall were soil conditions considered.

In the 20-year period analyzed, the days available followed a fairly definite pattern for most of the crop operations considered. Usually three or four years out of the 20 were considerably less favorable than the rest and three or four years were distinctly more favorable. The remaining years were fairly similar (see Chart Page 4). In view of this general pattern, the minimum days available 16 years out of 20 are reported in comparison with the average, worst, and best years.

Application of Results to Other Areas of Ohio

Does the weather at Columbus compare with other areas of the state? For analytical purposes, the Weather Bureau has divided the state into ten districts. To answer the question on the comparability of the climate at Columbus with the remainder of the state, the average or normal monthly rainfall, mean temperature, the probability of securing one inch or more of

rain in any week, and the days with .01 inch or more of rain were compared. Rainfall and temperature comparisons were for the period 1931-1955; probability of securing one inch or more of rain in any week was for the period 1901-1955, and days with .01 inch or more of rain was for the period ending December, 1920, and varying in years from 25-51 years among the ten stations. See Table II, III, and IV in the Appendix for data used in making comparisons.

For the nine months (March-November) the rainfall recorded at the Columbus Station was below any of the other ten districts. The differences were primarily during August, September, October, and November, with Columbus having almost two inches less than most of the other districts during these four months. However, during the soil-working and small grain harvest months of March, April, May, June, and July, the monthly rainfall was slightly below that reported in the other districts.

With respect to mean monthly temperature, Columbus is a little higher than two-thirds of the ten districts and a little lower than the others. The differences are small enough to permit the use of these findings in the other areas of the state except perhaps in the extreme north and extreme south.

The probability of receiving one inch or more of rain in a week as indicated by an analysis of each week from March 15 to July 25 was slightly less at Columbus in most weeks than in half of the districts and about the same as in the other half.[1/] The same was true for the period July 26 to November 28.

The number of days with more than .01 inch of rain, on the basis of the

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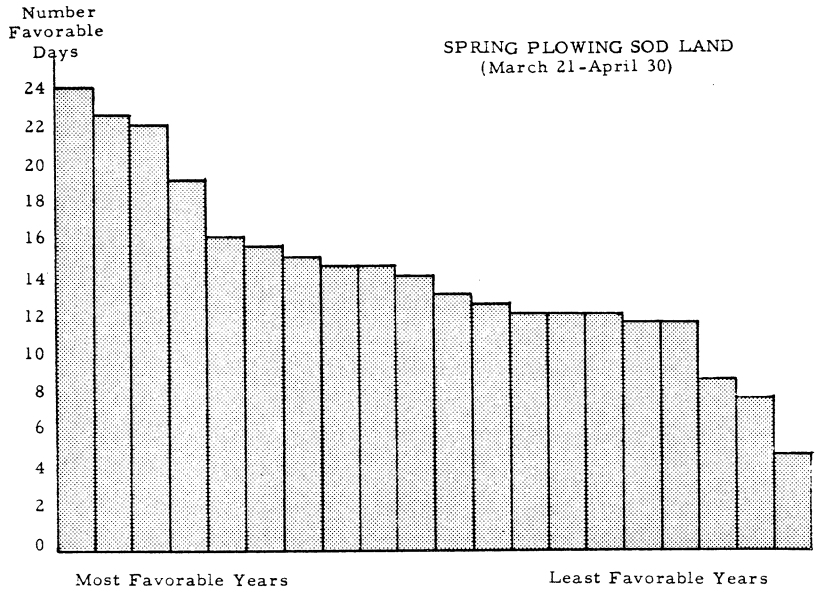
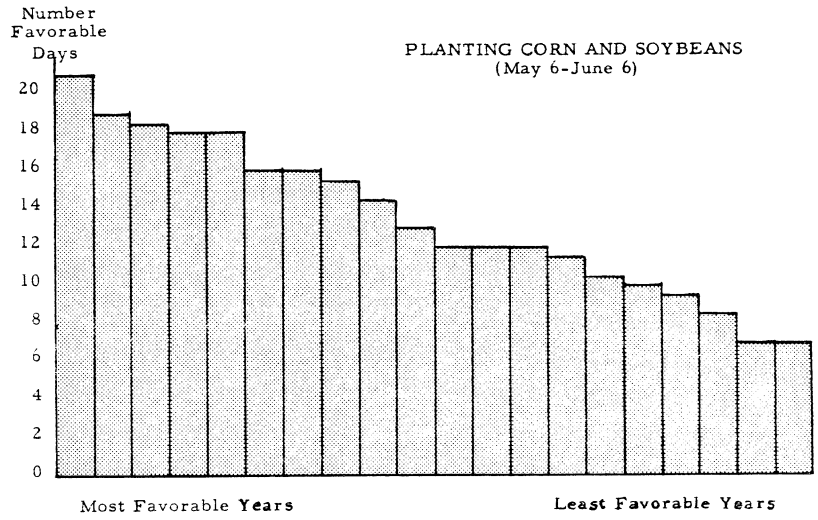
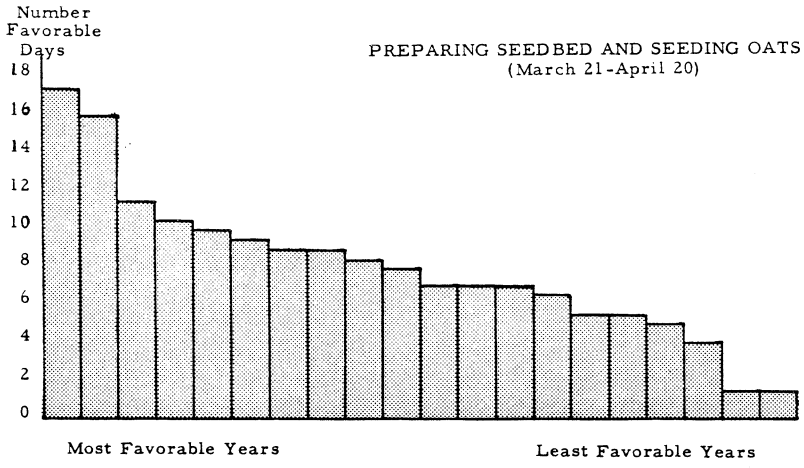
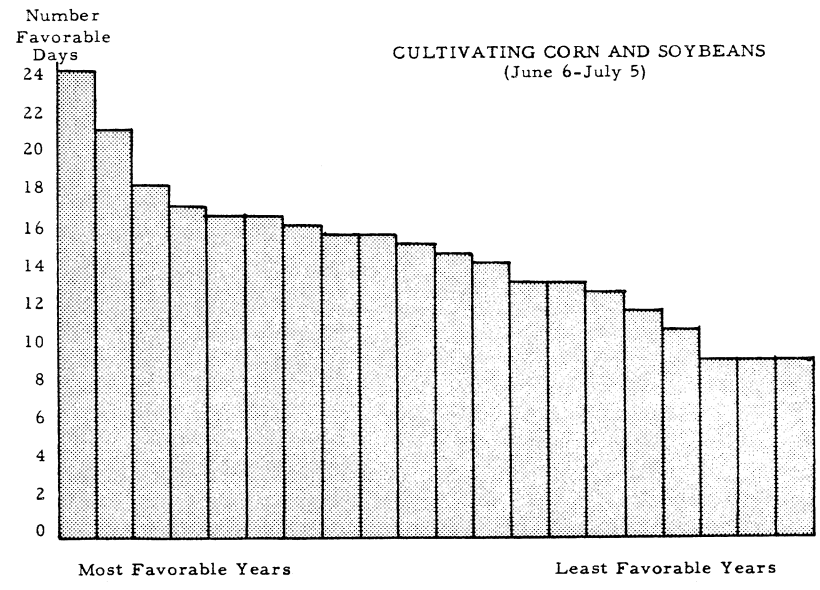
1/ G. L. Barger, R. H. Shaw, and R. F. Dale, Chances of Receiving Selected Amounts of Precipitation in the North Central Region of U.S., Agr. Exp. Station, Ames, Iowa, 1959. Page 207.









FAVORABLE DAYS AVAILABLE FOR SELECTED OPERATIONS ON AVERAGE DRAINED LAND DURING THE PERIOD 1938 - 1957

(With Years Arranged From Most Favorable to Least Favorable)

data available,[1/] was a little greater at Columbus than at the other stations used in the comparison. This apparently greater frequency of rainfall would have had a slightly greater restrictive effect on the number of favorable days available for crop operations than at the other stations. However, the slightly greater probability of receiving more than one inch of rain or more in a week in several of the other stations, together with a little heavier rainfall, would tend to offset the greater frequency of rains.

The differences that exist between weather conditions as reported by the Columbus Station and those reported in the ten districts would tend to result in slightly more time available at Columbus for the various farm operations studied than in several of the other districts. Although there are some differences in climate throughout the state, it seems reasonable to conclude that with minor exceptions (extreme north and extreme south) the findings of the study will be applicable throughout most of the state.

Sundays Included Among the Favorable Days

To simplify the analysis of the time available, no attempt was made to differentiate between Sunday and the other six days of the week. This was done on the assumption that the time available for performing field work Monday through Saturday could be accurately determined by reducing the total days found to be available for any particular operation by one-seventh.

Favorable Days for an Operation Are Not Exclusive of Favorable Days Available For Another Over-Lapping Operation

In determining the days available for one operation, no attempt was made to exclude the favorable days that might be used on another operation that competed for the same favorable days. For instance, spring plowing of sod

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1/ Periods compared were not all of same length, but 25 of the years were the same for all of the stations considered.

land, plowing of bare or stalk land, and seeding of oats overlap. Thus, they compete for many of the same favorable days during the spring season. If on a particular farm all three operations must be performed, the one with the smallest number of favorable days will have priority. However, sufficient machine and power capacity must be available to do the three operations within the favorable days available for the operations with the longest season or period in which the work may be performed. Spring plowing of sod would have a longer season without a reduction in yield than sowing oats, but all plowing for other crops and seeding of oats must be done within the time available for plowing sod land.

Soil Operations

Assumptions on Rates of Drying

Assumptions were made for three levels of water removal.1/ They were "good drainage," "average drainage," and "poor drainage." Good drainage assumed the removal of .20 inch of water per day, average drainage, .15 inch, and poor drainage, .10 inch.2/ In addition to water removed by drainage, there was that removed by evaporation from the soil surface and by transpiration through plants. Water drawn off daily by evaporation and transpiration increases from a negligible amount in the early spring to as much as .20 inch in June and July.3/ In determining days available for soil

1/ Water removal rates used in the study were established by the authors after conferring with Virgil Overholt, Agricultural Extension specialist in drainage at Ohio State University, and a study of water removal rates reported by Roe and Agres in Engineering for Agricultural Drainage, McGraw Hill Book Company, 1954, pages 252-253.

2/ On a few farms with very complete and well-engineered drainage systems and moderately porous soil, a rate of water removal of .30 inch or more per day will take place. On such farms there will be more days favorable for soil working operations than are indicated for good drainage in this study.

3/ Harold, L. L. and Dreibelbis, F. R., Agricultural Hydrology as Evaluated by Monolithic Lysimeters, Technical Bulletin 1050, USDA, 1951, page 60.

working operations, the rate of water removed by drainage was held constant but that removed by evaporation and transpiration was adjusted when daily mean temperature deviated significantly from the average.1/ The schedule of water removal by drainage, evaporation, and transpiration used in determining the days available for soil fitting operations is as follows:

	Good Drainage	Average Drainage	Poor Drainage
Mid-March	.20 inch	.15 inch	.10 inch
Mid-April	.25 inch	.20 inch	.15 inch
Mid-May	.30 inch	.25 inch	.20 inch
Mid-June	.35 inch	.30 inch	.25 inch
Mid-July	.40 inch	.35 inch	.30 inch

Whether a farm has good, average, or poor drainage is difficult to determine except through knowledge of the soil type drainage system and by observation over several years, including some with heavier than normal rainfall.

Good drainage would only be considered to exist where the soils were naturally well drained and where there was enough slope to prevent ponding, or where supplemented by sufficient tile to handle the ponding. It would also be considered to exist if the soils, though naturally slow to drain, were assisted by adequate tile to give rapid drainage.

Poor drainage would be considered to exist where soils were naturally heavy and slow to drain, where ponding occurred, and where there is little or no assistance from tile. It would also exist if well drained spots were intermingled with slow-draining soil types.

Average drainage would be considered to exist where water removal is readily recognized as neither completely satisfactory nor bad.

1/ Meyers, A. F., The Elements of Hydrology, 1928, Second Edition, John Wiley and Sons.

Plowing Sod Land

During the 20 years, 1938-1957, there was an average of 14.5 days out of the 41 between March 21 and April 30 when soil conditions were determined to be favorable for plowing sod under average drainage conditions. Only 12 days were favorable under poor drainage conditions and 17.5 days under good drainage conditions. (See Table I, Page 8) 1/ In the least favorable year of the 20 analyzed, there were only five days when soil conditions were suitable for plowing sod under average drainage conditions, 2.5 days under poor conditions, and 6.5 days under good drainage conditions.

Table I. Days Available for Plowing Sod By Selected Periods and Drainage Conditions, Central Ohio, 1938-1957

Drainage and Period	Total Days	Favorable Days Available			
		Average For Period	Worst Year	Best Year	Minimum 16 out of 20 years
Average Drainage					
Mar 21-Apr 30	41	14.5	5.0	24.5	12.5
Apr 1-May 10	40	17.0	8.5	23.5	13.0
Mar 10-May 10	62	23.0	13.0	35.5	16.5
Poor Drainage					
Mar 21-Apr 30	41	12.0	2.5	22.5	8.5
Apr 1-May 10	40	14.0	6.0	21.0	11.0
Mar 10-May 10	62	18.5	8.5	31.5	12.0
Good Drainage					
Mar 21-Apr 30	41	17.5	6.5	27.5	15.0
Apr 1-May 10	40	19.5	11.5	25.5	16.0
Mar 10-May 10	62	26.5	15.0	40.0	20.5

On the basis of the assumptions on drying rates, Central Ohio farmers with average drainage conditions may expect four years out of five to have 12.5 days or more when sod land will be suitable for plowing between March 21 and April 30.

1/ In determining the days available for plowing sod land, a slightly higher rate of water removal was used than shown above to allow for the transpiration that occurred due to the sod. It was also assumed that the better traction made possible by the sod would permit a little quicker return after a rain than in the case of bare land.

Plowing Bare or Stalk Land

Generally there is less time when bare or stalk land is suitable for plowing than in the case of sod land. The available time is reduced because very little transpiration of moisture takes place. Furthermore, the "soapy" surface conditions following light freezes and showers, reduces the available time.

Under average drainage conditions, 12.0 days were favorable for plowing bare or stalk land between March 21 and April 30. With poor drainage conditions, 8.5 days, and with good drainage conditions, 14.5 days, were found to be suitable for plowing (See Table II, page 9). In the least favorable year of the 20, there were only 2.5 days when conditions were considered to be suitable under average drainage. With poor drainage there was no time when conditions were favorable, but with good drainage there were 5.0 days when bare or stalk land could be plowed.

Table II. Days Available for Plowing Bare or Stalk Land, by Selected Periods and Drainage Conditions, Central Ohio, 1938-1957

Drainage and Period	Total Days	Favorable Days Available			
		Average For Period	Worst Year	Best Year	Minimum 16 out of 20 years
Average Drainage					
Mar 21-Apr 30	41	12.0	2.5	22.5	8.5
Apr 1-May 10	40	14.0	6.0	21.0	11.0
Mar 10-May 10	62	18.5	8.5	31.5	12.0
Poor Drainage					
Mar 21-Apr 30	41	8.5	0.0	18.5	5.5
Apr 1-May 10	40	11.5	4.0	17.0	7.5
Mar 10-May 10	62	14.0	5.0	26.5	7.5
Good Drainage					
Mar 21-Apr 30	41	14.5	5.0	24.5	12.5
Apr 1-May 10	40	17.0	8.5	23.5	13.0
Mar 10-May 10	62	23.0	13.0	35.5	16.5

Sowing Oats

Sowing oats, as used here, involves all of the spring work normally performed on the land in connection with putting in the crop.

During the 31-day period, March 21 to April 20, under average drainage conditions, there was an average of eight days on which the soil operations necessary to seeding an oats crop could take place during the 20 years (see Table 3, page 12). This 31-day period is the one that generally results in the highest oats yields in Central Ohio. Under poor drainage conditions, there were 5.5 days on the average when the soil and climatic situation was favorable. With good drainage conditions there was an average of 10.0 favorable days.

One year out of five, or 20 per cent of the time, there were less than 5.5 days on the average-drained land and less than 2.5 days on poorly drained land when the seeding of oats could take place. In terms of equipment and labor, this means a farmer with average-drained land would need machine capacity and a labor crew large enough to fit the land, including plowing, if this were the practice followed, as well as sowing the oats on the acres to be seeded in 5.5 days if he wished to get his crop in during the optimum period, four years out of five. A farmer with poorly drained land would need equipment and labor to do the job in 2.5 days.

In the least favorable year, 1940, there were only 1.5 favorable days with average drainage, none with poor drainage, and 3.0 days with good drainage. Extending the sowing period to April 30 in the least favorable year added two favorable days where drainage was good, one day where it was average, and none where drainage was poor.

Soil Fitting Operations Preceding Final Seedbed Preparation for Corn or Soybeans

This analysis was made to provide data for those operators who generally disc, harrow, or drag their plowed land between plowing and the final seed-

bed preparation for corn, soybeans, or other similar spring crops.

In Central Ohio, most field work of this type takes place between April 16 and May 5. Since plowed land is free of plant growth, drying following rain depends on evaporation and drainage. The rate of moisture removal by drainage is essentially the same as during the plowing period. However, surface evaporation is somewhat more rapid due to higher temperature and the porous nature of the soil surface. Taking these factors into account, an average of eight days was found to be available per year with at least 2.5 days 16 years out of 20 under average drainage conditions (See Table IV, page 12). In the least favorable year, 1947, there was no time when the soil and climatic conditions would have permitted soil fitting operations between April 16 and May 5, irrespective of drainage conditions.

Final Seedbed Preparation and Planting Corn and Soybeans

Planting dates for corn and soybeans overlap sufficiently in Central Ohio so that no attempt was made to analyze the time available for each separately. Practically all of the farmers in the area try to plant corn and soybeans between May 6 and June 5.

The majority of Central Ohio farmers attempt to complete soil fitting and planting between May 11 and May 31. In this period, there was an average of 8.5 days when soil and climatic conditions were considered favorable for the fitting and planting operations under average drainage conditions. Under such drainage conditions, a minimum of five days were available 16 years out of the 20. In the worst year, there were only two days when fitting and planting operations could have been carried on (See Table V, page 13). Under poor drainage conditions, the least time available 16 years out of 20 was 3.5 days and with good drainage conditions, 6.5 days.

Table III. Days Available for Seeding Oats by Selected Periods and Drainage Conditions, Central Ohio, 1938-1957

Drainage and Period	Total days	Favorable Days Available			
		Average for Period	Worst Year	Best Year	Minimum 16 out of 20 Years
Average Drainage					
Mar 21-Apr 20	31	8.0	1.5	17.5	5.5
Apr 1-Apr 30	30	8.8	1.5	16.5	6.0
Mar 21-Apr 30	41	11.7	2.5	22.5	8.5
Poor Drainage					
Mar 21-Apr 20	31	5.5	0.0	13.0	2.5
Apr 1-Apr 30	30	6.7	0.0	15.0	4.0
Mar 21-Apr 30	41	8.5	0.0	18.5	5.5
Good Drainage					
Mar 21-Apr 20	31	10.0	3.0	19.0	7.5
Apr 1-Apr 30	30	11.3	4.0	18.0	8.0
Mar 21-Apr 30	41	14.6	5.0	24.5	12.5

Table IV. Days Available for Soil Fitting Operations Preceding Final Seedbed Preparation by Selected Periods and Drainage Conditions, Central Ohio, 1938-1957

Drainage and Period	Total days	Favorable Days Available			
		Average for Period	Worst Year	Best Year	Minimum 16 out of 20 Years
Average Drainage					
Apr 16-May 5	20	8.0	0.0	16.0	2.5
Apr 21-May 10	20	9.0	1.5	17.0	6.5
Apr 11-May 10	30	11.5	4.5	20.0	7.0
Poor Drainage					
Apr 16-May 5	20	6.5	0.0	13.5	2.0
Apr 21-May 10	20	7.5	1.0	15.0	5.0
Apr 11-May 10	30	9.0	4.0	16.5	6.0
Good Drainage					
Apr 16-May 5	20	9.0	0.0	17.5	5.0
Apr 21-May 10	20	10.5	2.5	17.0	8.0
Apr 11-May 10	30	13.5	6.0	21.0	9.0

Table V. Days Available for Final Seed Preparation and Planting Corn and Soybeans by Selected Periods and Drainage Conditions, Central Ohio, 1938-1957

Drainage and Period	Total Days	Favorable Days Available			
		Average for Period	Worst Year	Best Year	Minimum 16 out of 20 Years
Average Drainage					
May 6-June 5	31	13.5	7.0	21.0	10.0
May 11-May 31	21	8.5	2.0	18.0	5.0
May 16-June10	26	11.5	4.0	17.0	9.0
Poor Drainage					
May 6-June 5	31	11.5	4.0	21.0	7.0
May 11-May 31	21	7.5	1.0	17.0	3.5
May 16-June10	26	9.5	1.0	17.5	6.5
Good Drainage					
May 6-June 5	31	15.0	9.5	21.0	12.0
May 11-May 31	21	9.5	3.5	19.0	6.5
May 16-June10	26	12.5	6.5	20.0	11.5

Cultivating Corn and Soybeans

Cultivating of corn and soybeans in Central Ohio is done during June and the first few days of July. At this time drying following rain is at a much higher rate than in April and May due to the effect of the higher average temperature on evaporation and on transpiration through plant growth. Transpiration continues to increase as the size of the plant increases, thus the rate of drying following a rain is greater at the end of the cultivating period than at the beginning.

In the period June 6 to July 5, when the major part of the cultivating normally takes place, 15 days were favorable for this operation on average drained land. (See Table VI, page 14) On well-drained land the average number of favorable days was 16.5 and on poorly drained land, 13.0 days.

Table VI. Days Available for Cultivating Corn and Soybeans by Selected Periods and Drainage Conditions, Central Ohio, 1938-1957

Drainage and Period	Total Days	Favorable Days Available			
		Average for Period	Worst Year	Best Year	Minimum 16 out of 20 Years
Average Drainage					
June 6-July 5	30	15.0	9.5	24.5	12.0
May 26-June 25	31	15.0	8.0	23.0	10.5
June 16-July 15	30	16.0	8.5	26.0	13.5
Poor Drainage					
June 6-July 5	30	13.0	6.5	23.0	10.5
May 26-June 25	31	12.5	4.5	21.0	8.5
June 16-July 15	30	14.5	6.5	25.5	11.5
Good Drainage					
June 6-July 5	30	16.5	10.5	25.5	14.0
May 26-June 25	31	16.0	10.5	24.0	13.5
June 16-July 15	30	17.5	10.5	26.0	15.0

Seeding Fall Sown Small Grain

Normally the soil is in a dry condition in the fall as contrasted to the frequently saturated situation in the spring. Consequently, during many of the years drainage had little or no effect on the days available for fall seeding operations. The most significant difference occurred in years that had unusually wet weather in the late summer and early fall. As a result, only two levels of drainage were considered for seeding of fall grains.

The same procedure was followed in estimating the days available as was followed for soil operations in the spring and early summer. Daily and accumulated rainfall, temperature, sunshine, and wind were the factors used in deciding if conditions were favorable. On average to well-drained land, the rate of drying after a rain used in the analysis was .40 inch per day

and on poor to average drained soil, the rate used was .30 inch per day.

In the 37-day period from September 25 to October 31, there was an average of 27.5 days when wheat, barley, or rye could have been seeded on average to well-drained land (See Table VII, Page 15). Eighty per cent of the years analyzed had 24.5 or more favorable days available for this operation. In the worst year, there were 19.5 days, and in the best year, 33.5 days. The average number of days available on average to poorly drained land dropped to 26.0 days with 21.5 days or more 80 per cent of the years.

Table VII. Days Available for Seeding Fall Sown Grain by Selected Periods and Drainage Conditions, Central Ohio, 1938-1957

Drainage and Period	Total Days	Favorable Days Available			
		Average for Period	Worst Year	Best Year	Minimum 16 out of 20 Years
Average to Well-Drained Land					
Sept 25 - Oct 31	37	27.5	19.5	33.5	24.5
Sept 25 - Oct 15	21	16.0	11.5	21.0	12.5
Oct 5 - Oct 25	21	16.0	9.0	20.0	14.5
Oct 10 - Oct 31	22	16.5	11.5	22.0	14.0
Poor to Average-Drained Land					
Sept 25 - Oct 31	37	26.0	17.0	33.5	21.5
Sept 25 - Oct 15	21	14.5	8.5	21.0	11 5
Oct 5 - Oct 25	21	15.0	7.0	20.0	13.5
Oct 10 - Oct 31	22	15.5	9.5	22.0	13.0

Summary of Favorable Days for Soil Operations in the Spring and Early Summer

The period March 21 to July 15 includes 117 days. In this period, spring plowing, soil fitting, planting, and cultivating operations take place. During the 20 years covered by the study, there was an average of 49.0 days, including Sundays, or 43.0 per cent of the 117 days when average drained soils were suitable for working. In the least favorable year, there were only 34.0 days. However, 80 per cent of the time, or four years out of five, Central

Table VIII. Days Analyzed as Favorable for Soil Working Operations in Central Ohio By Selected Periods and for Three Levels of Drainage for the Period, 1938-1957[1/]

Level of Drainage	March 21-31	April 1 -30	May 1-31	June 1-30	July 1-15	March 21-July 15
	(Days favorable for soil working operations)					
Average Drainage						
Average 1938-1957	2.8	8.9	13 9	14.5	8.9	49.0
Worst Year	0.0	1.5	6.0	6.5	3.5	34.0
Best Year	8.5	16.5	26.0	22.0	13.0	67.5
Minimum 15 out of 20 yrs.	1.0	6.0	11.5	11.0	7.0	43.5
Poor Drainage						
Average 1938-1957	1.8	6.7	11.8	12.5	8.3	41.5
Worst Year	0.0	0.0	3.0	4.0	3.5	25.0
Best Year	8.5	15.0	26.0	21.0	13.0	60.0
Minimum 16 out of 20 yrs.	0.0	4.0	8.0	8.5	6.0	35.0
Good Drainage						
Average 1938-1957	3.4	11.2	15.4	16.1	9.6	55.7
Worst Year	0.0	4.0	8.5	9.0	4.5	41.5
Best Year	8.5	18.0	26.0	23.0	13.0	74.0
Minimum 16 out of 20 yrs.	2.0	8.0	13.0	12.5	7.5	50.0

1/ For details by years, see Tables V, VI, and VII in Appendix, Pages 5-7.

Ohio farmers had 43.5 days or more per season (see Table VIII, page 16).

As the season progressed, an increasingly greater proportion of the days were suitable for soil working operations. This was due primarily to a more rapid withdrawal of moisture through evaporation and transpiration where plants such as corn and beans were growing. In late March, about one day in four on average-drained land was suitable for soil working operations, about one in three in April, and slightly less than one out of two in May and June.

The least favorable spring and early summer periods for soil working operations occurred in 1947, 1943, 1940, and 1956, in the order named. For the least favorable years for specific soil working operations see Table IX, Page 18.

Harvesting Meadow Crops

Harvesting field-cured meadow crops presents a different situation in regard to the effect of climate on the time available. As soon as the soil is dry, in the case of soil-working tasks, or as soon as the grain is dry enough for combining or picking, the operation can be initiated. Completion occurs acre by acre as the machine moves over the land. This is not true in meadow crop harvest except for the direct chopping of grass silage. Field curing of hay must be initiated one day (cutting meadow) and completed one or more days later (storing). Thus, a period of favorable weather must exist to complete the job successfully.

Two systems for harvesting hay were considered: (1) conventional field curing, and (2) field curing aided by the use of a stem crusher or hay conditioner. The method of moving from the windrow(loose, baled or chopped) was not considered as affecting significantly the time required for the curing to take place.

Table IX. The Three Least Favorable Years on Average-Drained Land by Selected Soil-Working Operation, Central Ohio, 1938-1957

Operation	Period		Rank according to favorable days*		
			18th	19th	20th
Plowing Sodland	Mar. 21-Apr.	30	1954	1944	1940
Plowing Bare or Stalk Land	Mar. 21-Apr.	30	1954	1944	1940
Preparing For and Seeding Oats	Mar. 21-Apr.	20	1938	1944	1940
Preparing Seedbed and Planting Corn and Beans	May 6-June	5	1944	1956	1947
Cultivating Corn and Beans	June 6-July	5	1957	1951	1939

*Best year given rank of one and least favorable rank of 20.

Assumption on Drying Time

Relatively little data based on actual measurements are available on field drying time required for the different methods. Work done in Illinois indicated that with an average yield of hay the minimum drying time for conventional field curing would be two days after the day of cutting.[1/] Some recent studies, including one in Ohio, on the effect of hay crushers or conditioners on field curing indicate a reduction of one full day under that required for unconditioned hay. On the major part of the farms included in the Ohio study, conditioned hay was taken in the day following cutting when no rain intervened and when drying conditions were reasonable favorable. About half of these farmers stored unconditioned hay on the second day after it was cut. The average time from cutting to storage without the assistance

1/ Rameer and Kleis, University of Illinois Circular 693 "Hay Crushing for Faster Field Curing," June 1952.

of a conditioner was over three days because of intervening adverse weather.[1/]

In light of the above findings, together with the observations of several experienced farmers, the following assumptions were made and employed in appraising the limiting effect of climate on the hay-making operation:

Conventional Field Curing--A minimum of three days, including the day of cutting, would be needed with no intervening rain heavier than a trace; two of the days must have good drying conditions and the other day would need to be a fair drying day. Neither two fair and one good day nor two good and one poor day was considered adequate. If a rain intervened, the curing period was extended until sufficient drying days followed the rain to permit adequate drying. When rain increased soil moisture significantly, a longer period or more favorable drying conditions were assumed necessary.

Field Curing Aided by Hay Conditioners--A minimum of two days, including the day of cutting, would be needed with no intervening rain heavier than a trace; both days would need to be good drying days. When less favorable drying existed, it was assumed more drying time than two days would be needed. Two fair and one good day or three fair days, including the day of cutting, were assumed adequate to permit storage the second day after cut. When an intervening rain occurred, the subsequent drying period was determined the same as in the case of conventional field curing with only slightly less drying time or conditions assumed necessary. This was done on the belief that the major advantage of the stem crusher was to hasten the original drying.

1/ C. V. Moore, J. H. Sitterley, and E. T. Shaudys, Costs of Hay Conditioning for Faster Field Curing, Research Bulletin 834, Ohio Agricultural Experiment Station, 1959.

Amount of Meadow Cut--It was assumed that no more meadow crop would be cut in any one day than could be stored in one day after it reached a satisfactory moisture level to be stored.

The days in each of the three harvest periods--June 1-30, July 15-August 15, and September 1-20--were analyzed to see how many had no rain heavier than a trace between 6:00 a.m. and 6:00 p.m. (data were available for each 6-hour period). The rainless days (6:00 a.m. to 6:00 p.m.) were analyzed as to drying conditions and classified as good, fair, or poor drying days. (See Table X below.) Temperature, wind, per cent of possible sunshine, humidity, and precipitation between 6:00 a.m. and 6:00 p.m. were the factors considered in determining into which class a given day would fall. If rain heavier than a trace occurred between 6:00 p.m. and 6:00 a.m., it was taken into account as an intervening rain in arriving at the time required for a cure to occur.

Table X. Hay Drying Conditions Prevailing during the Periods for First, Second, and Third Cutting, Central Ohio, 1938-1957[1/]

Cutting	Total Days	Days Without Rain Between 6 a.m. & 6 p.m. with Drying Conditions Classified As:			Days With Rain Between 6 a.m. and 6 p.m.
		Good	Fair	Poor	
First Cutting	(June 1-30)				
Average	30	10.9	5.6	6.6	6.9
Range	30	6-17	2-9	3-12	3-11
Second Cutting	(July 15-Aug 15)				
Average	32	12.8	8.2	5.9	5.1
Range	32	6-21	4-11	2-10	2-8
Third Cutting	(September 1-20)				
Average	20	8.1	3.9	4.8	3.2
Range	20	2-14	1-7	2-10	1-5

1/ See Table VIII, Page 8 in Appendix, for data by years.

Days Required for Sufficient Cure to Take Place to Permit Storage When Meadow Was Cut on Any Day Favorable for Mowing

An average of 24.6 days was determined to have weather conditions favorable for mowing first-growth meadow crops. One year, 1939, had as few as 21 favorable days, and in 1953 there were as many as 28 days. A day was considered to be favorable for cutting meadow if either the forenoon or afternoon had no rain heavier than a trace and not more than .3 inch occurred between 12:00 a.m. and 6:00 a.m. A favorable half day either before or after noon was recorded as a full day since on most farms a half day of mowing with a tractor mower will cut as much hay as can be stored in a day with the typical crew and equipment. The days recorded as favorable for mowing were frequently greater than the rain-free days since some rain during a 24-hour period would not preclude mowing unless it was heavy or spread over the daylight hours.[1/]

During the 20 years analyzed, there was an average of six days out of 24.6 favorable days for mowing first-growth meadow followed by weather conditions permitting a satisfactory field cure in three dyas, including the day in which it was cut. On six days it would have required three days after cutting or a total of four days for storage to take place. On four days storage would have been delayed to four days, and on eight days of the 24 favorable for cutting, the climate was such that storage would have been delayed five or more days after the day cut (See Table XI, Page 22). In the worst year, 1957, meadow cut on 12 of the 22 favorable days for cutting would have had to remain in the field five or more days before it would have been dry enough to store.

1/ Soil conditions were not taken into account in deciding whether a day was favorable for cutting. Unquestionable, there were a few of the days considered favorable for cutting when all or part of the day would have been unsatisfactory for cutting because the soil would not have supported the weight of a power unit.

Table XI. Making Hay by Field Curing - Number of Days When Meadow Could Have Been Cut and the Length of the Subsequent Curing Period Required, 1938-1957

Cutting	Total Days Favorable For Cutting Meadow	Favorable Cutting Days Which Were Followed By Weather Conditions Estimated to Require:			
		Two Days After Day on Which Cut For Field Curing	Three Days After Day On Which Cut For Field Curing	Four Days After Day On Which Cut For Field Curing	Five Days Or More After Day On Which Cut For Field Curing
First Cutting, June 1 - 30					
Average Number	24.6	6.0	5.8	4.2	8.6
Number in Worst Year	22.0	4.0	4.0	2.0	12.0
Number in Best Year	26.0	11.0	5.0	6.0	4.0
Minimum 16 Years Out of 20	22.0	4.0	3.0	6.0	9.0
Second Cutting, July 15-August 15					
Average Number	27.9	7.9	8.6	5.3	6.1
Number in Worst Year	26.0	4.0	4.0	4.0	14.0
Number in Best Year	30.0	16.0	9.0	1.0	4.0
Minimum 16 Years Out of 20	29.0	4.0	8.0	10.0	7.0
Third Cutting September 1-20					
Average Number	17.1	4.3	4.7	3.4	4.7
Number in Worst Year	16.0	0.0	1.0	5.0	10.0
Number in Best Year	19.0	6.0	10.0	2.0	1.0
Minimum 16 Years Out of 20	16.0	2.0	4.0	2.0	8.0

Many farmers mow hay on any day favorable for cutting. When this is done, the probability is that during a 20-year period, a farmer would store 25 per cent of his hay two days after the day cut, 23 per cent three days after the day cut, 17 per cent four days after the day cut, and 35 per cent would have had to remain in the field five or more days after the day cut.[1/] The probability of meadow cut on any favorable day for cutting being stored the first, second, third, fourth, or fifth day after cutting is listed by cuttings and by curing methods in Table XII, Page 24.

The use of a stem crusher or hay crimper greatly increased the probability that meadow cut any favorable day could be stored within two days after cutting over the probability of doing so by conventional field curing (See Table XIII, Page 25). With hay conditioners, 49 per cent of the first cutting could have been stored by the second day after cutting compared with 25 per cent when conventionally cured (See Table XII, Page 24)

Harvesting Meadow as Grass Silage

In determining the effect of climate on days available for harvesting meadow crops as silage, it was assumed that meadow could be cut and stored as silage on any day that was favorable for cutting meadow. In some seasons with above normal rainfall or after brief periods of very heavy rainfall, a few of the days favorable for cutting meadow would not be suitable for harvesting silage because the soil would not support heavy harvesting equipment. No attempt was made to determine the number of such days.

On the basis of the above assumptions, there would have been an average of 24 days between June 1-30, 28 days between July 15 and August 15, and 17 days between September 1-20 when meadow crops could have been harvested

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1/ No attempt was made to determine how the probability would be affected if cutting was based on local weather predictions.

Table XII. Probability of Hay Being Stored Within One, Two Three, Four, and Five or More Days After Cutting, by Cuttings, When Cured by Different Methods as Determined By Analysis of the Climatic Conditions in Central Ohio, 1938-1957[1/]

Cutting and Curing Method	Days On Which Meadow Could Be Cut	Percent of Days when Meadow Could Have Been Cut Followed by Weather Conditions Permitting Storage Within Designated Days After The Day Cut				
		One Day	Two Days	Three Days	Four Days	Five or More
First Cutting (June 1-30)						
Conventional Curing						
Average Year[2/]	24	--	25	23	17	35
Worst Year	22	--	18	18	9	55
Min 16 Out of 20 Yrs	22	--	;8	;4	27	41
Stem Crusher Used						
Average Year	24.5	25	24	13	13	25
Worst Year	23	4	22	22	4	48
Min 16 Out of 20 Yrs	24	12	25	17	4	42
Second Cutting (July 15-Aug 15)						
Conventional Curing						
Average Year	23	--	28	31	19	22
Worst Year	26	--	15	15	15	55
Min 16 Out of 20 Yrs	29	--	14	28	34	24
Stem Crusher Used						
Average Year	28	30	26	23	10	11
Worst Year	26	8	20	12	16	44
Min 16 Out of 20 Yrs	28	18	29	39	7	7
Third Cutting (Sept. 1-20)						
Conventional Curing						
Average Year	17	--	25	28	20	27
Worst Year	16	--	0	6	31	63
Min 16 Out of 20 Yrs	16	--	13	25	12	50
Stem Crusher Used						
Average Year	17	26	23	18	12	21
Worst Year	16	0	0	31	13	56
Min 16 Out of 20 Yrs	16	19	19	6	12	44

1/ Probability is chances in 100.

2/ The selection of average year, worst year, and the 16th year out of the 20th was done by arraying the 20 years from best to worst based on the per cent of the crop stored 3 days after cutting in case of conventional curing and 2 days after cutting for the other two methods, with consideration for number of days requiring 5 or more days after the day cut to permit storage.

Table XIII. Making Hay with the Aid of a Stem Crusher - Number of Days When Meadow Could Have Been Cut and the Length of the Subsequent Curing Period Required, 1938-1957

Cutting	Total Days Favorable For Cutting Meadow	Days Favorable for Cutting Which Were Followed By Weather Conditions Estimated to Require:				
		One Day After Day on Which Cut For Field Curing	Two Days After Cutting	Three Days After Cutting	Four Days After Cutting	Five or More Days After Day On Which Cut For Field Curing
First Cutting, June 1-30						
Average Number	24.6	6.0	6.0	3.2	3.2	6.0
Number in Worst Year	23.0	1.0	5.0	5.0	1.0	11.0
Number in Best Year	26.0	8.0	12.0	2.0	4.0	0.0
Minimum 16 Years Out of 20	24.0	3.0	6.0	4.0	1.0	10.0
Second Cutting, July 15-August 15						
Average Number	27.9	7.8	6.8	6.0	2.7	4.6
Number in Worst Year	26.0	2.0	5.0	3.0	2.0	14.0
Number in Best Year	30.0	11.0	12.0	4.0	1.0	2.0
Minimum 16 Years Out of 20	26.0	7.0	6.0	1.0	4.0	8.0
Third Cutting, September 1-20						
Average Number	17.1	4.4	4.0	3.1	2.1	3.5
Number in Worst Year	16.0	0.0	0.0	5.0	2.0	9.0
Number in Best Year	19.0	12.0	4.0	---	2.0	1.0
Minimum 16 Years Out of 20	16.0	3.0	3.0	1.0	2.0	7.0

for silage. These are considered maximum days since in some years there would be days when the soil would be too wet to support harvesting equipment without damage to the land.

Harvesting Small Grain and Soybeans

The number of days favorable for combining grain was determined in much the same way as the days favorable for harvesting hay. Each day during the period was analyzed as to the drying conditions prevailing during the day and was classed as a good, fair, or poor day. Precipitation, sunshine, wind, temperature, and humidity between 6:00 a.m. and 6:00 p.m. and precipitation before 6:00 a.m. were the factors considered in determining the type of day.

Two levels of moisture were used in determining the number of favorable days available for harvesting small grain crops. The first called for a moisture content of 14 per cent or less in the standing grain which would make possible storing the crop without risk or marketing it without moisture dockage. The second level was for a moisture content of 16 per cent or less. At this level, some of the grain would have to be dried if stored or would be subject to moisture dockage if marketed direct from the combine.

When estimating the number of favorable days available for harvesting operations, each rain-free day was considered in light of the weather prevailing that day and conditions prevailing on previous days. In was assumed that more drying time would be required following a heavy rain or a period of two or three days of wet weather than would be needed after a moderate rain preceded by several dry days. A light shower after the grain was dry, if immediately followed by a good drying day, was not assumed to stop combining for more than a day.

Combining Wheat and Oats

On the basis of the procedure outlined above, there was an average of

nine whole days and two half days between July 5 and 31 when wheat or oats could have been combined at 14 per cent or less moisture and 11 whole and four half days at 16 per cent or less during the 20-year period. (See Table XIV, Page 27) In the least favorable year, there were only two whole and three half days when combining could have been done with 14 per cent or less moisture and five whole and three half days with 16 per cent or less. In 16 of the 20 years, the least time found to be available for combining at 14 per cent or less moisture was six whole and four half days and at 16 per cent or less and nine whole and two half days.

Table XIV. Combining Wheat and Oats - Favorable Days Available Between July 5 and 31 for Two Levels of Moisture, 1938-1957

Period and Level of Moisture	Total Days In the Period	Favorable Days Available 1/			
		Average For the Period	In the Worst Year	In the Best Year	Minimum Days Available, 16 Years Out of 20 2/
July 5-31					
14% moisture or less	27	9 whole & 2 half days	2 whole & 3 half days	17 whole & 3 half days	6 whole & 4 half days
16% moisture or less	27	11 whole & 4 half days	5 whole & 2 half days	18 whole & 5 half days	9 whole & 2 half days

1/ In determining the days available, half as well as whole days were recorded. Whole days were defined as those with some favorable time both before and after noon. Half days accounted for approximately 12 per cent of the time analyzed as favorable for combining with 14 per cent or less moisture and 15 per cent of the time for combining with 16 per cent or less moisture.

2/ See Table IX, Page 9 in Appendix, for individual years.

In terms of equipment, this would mean that the farmer, to harvest his wheat and oats four years out of five in the favorable days available between July 5-31 at 14 per cent or less moisture, would need machine-capacity to do the job in eight combining days. Those who did not work on Sunday

would require one-seventh more capacity.

Combining Soybeans

Two periods were analyzed (See Table XV, Page 29). The first period, September 26 to October 16, was analyzed to provide information for farmers with early weed-free beans. The second period, October 17 to November 6, was set up for farmers with late or weedy beans. In both instances, it was assumed that the beans were mature and that weather conditions were the only factors affecting the moisture content of the beans. As in the case of wheat and oats, no empirical data were found that could serve as a basis for determining drying rates. Therefore, the experience of selected farmers and observations of the authors formed the basis for determining the favorable combining days.

In the September 26-October 16 period, there was an average of ten whole days and three half days when it was considered possible to combine beans at 14 per cent moisture or less, and 12 whole days and two half days at 16 per cent moisture or less (See Table XV, Page 29). In the least favorable of the 20 years, the analysis indicated that there were only two whole and two half days when beans could have been combined at 14 per cent moisture or less, and four whole and two half days at 16 per cent moisture or less.

In the October 17 to November 6 period, shorter days, lower temperature, and slightly more soil moisture resulted in about 20 per cent fewer favorable days than in the early period.

Harvesting Corn

The nature of corn picking is such that once the moisture in the corn has dropped to a level considered safe for storage, climate plays a less important role than in the case of meadow crops and small grains. After the corn is mature enough to store, it is largely a matter of the ground being dry enough to support equipment.

Table XV. Combining Soybeans - Favorable Days Available in Central Ohio During Two Different Periods and at Two Levels of Moisture, 1938-1957

Period and Level of Moisture	Total Days In The Period	Favorable Days Available 1/			
		Average for the Period	In The Worst Year	In The Best Year	Minimum Days Available 16 Years Out of 20 2/
September 26-October 16					
14% moisture or less	21	10 whole days, 3 half days	2 whole & 2 half days	18 whole & no half days	5 whole & 3 half days
16% moisture or less	21	12 whole days, 2 half days	4 whole & 2 half days	20 whole & no half days	6 whole & 2 half days
October 17-November 6					
14% moisture or less	21	8 whole days, 3 half days	4 whole & 1 half day	16 whole & 1 half day	5 whole & no half days
16% moisture or less	21	9 whole days, 2 half days	5 whole & 1 half day	17 whole & 2 half days	6 whole & 2 half days

1/ In determining the days available, half as well as whole days were recorded. Whole days did not necessarily mean a full 8 or 10 hours of operation, but the availability of some favorable time in both the forenoon and afternoon. Likewise, a half day did not mean 4 or 5 hours but some favorable time either before or after noon. Half days accounted for 10-15 per cent of total favorable time available.

2/ See Table X, Page 10 in Appendix for individual years.

Occasionally, extreme dryness of the fodder prevents picking. However, no attempt was made in this study to exclude the portion of the time when the corn was too dry to pick. Rainfall during the day, accumulated rainfall, and temperature were the main factors considered in determining the days available. Temperature was considered only when it was such as to result in freezing during the night and was high enough to cause thawing during the day. Such temperatures were considered to be unfavorable for picking because of the resulting slippery condition of the soil. If the temperature remained below freezing, thus preventing thawing, it was not considered unfavorable.

Difference in drainage conditions, except in extremely wet periods, did not greatly alter the days available because of normal dryness of the soil in the fall and the rapidity with which rain tended to be absorbed.

Three periods were analyzed: an early period, October 1 to October 31, for those with early maturing corn or drying facilities; a late period, November 1 to November 30, for seasons in which maturity was late; and an intermediate period, October 15 to November 15 (See Table XVI, Page 30). An average of 23.5 days in the first period, 21.5 days in the intermediate period, and 16 days in the late period were determined to be favorable for picking during the 20-year period.

Table XVI. Days Available for Harvesting Corn with Conventional Picker by Selected Periods, Central Ohio, 1938-1957

Period	Total Days	Average for Period	Worst Year	Best Year	Minimum 16 Years Out of 20
Oct 1 - Oct 31	31	23.5	13.0	28.0	22.5
Nov 1 - Nov 30	30	17.0	7.0	23.5	13.0
Oct 15 - Nov 15	32	22.5	15.5	30.5	20.0

Application of Data

To equip his farm with enough machinery and power to do satisfactorily all of the field work in the years with the least favorable weather, the farmer would be required to make a large outlay of capital. Furthermore, it would establish a high annual overhead cost. A significantly lower total investment and annual overhead cost would be incurred if the farm were equipped to do the field work in those years when the time available to do such work was average. However, if the latter course were pursued, difficulty would be encountered in accomplishing satisfactorily many of the tasks in the seasons with below average days available for field work. Also, in the least favorable years, actual losses could be expected from reduced plantings, lower yields, and poorer quality due to delayed planting and harvesting.

Either situation, equipping to do the job in the worst year or equipping to do it in an average year, is likely to affect adversely the farmer's long-time average net income.

The following is an attempt to demonstrate the effect on investment and to illustrate briefly how information on days available to do selected farm operations may be used:

For the purpose of illustration, let us assume we are equipping a Central Ohio farm containing 200 acres of cropland. It is to be a general livestock farm consisting of hogs and fat cattle. The crop rotations and average annual acreages are: corn, 75; soybeans, 25; oats, 25; wheat, 25; mixed alfalfa-clover-timothy meadow, 50. The crop program calls for plowing for corn and soybeans with the 50 acres of corn following sod and 25 acres following corn. The soybeans will follow corn and in turn be followed by wheat. The oats will follow second-year corn. Soil type, topography,

and tile drainage on the farm places it in the category of average drainage. The farmer, a man in his 30's, is the only labor supply. Occasionally a few days of seasonal labor can be hired. In some of the operations an exchange of labor and equipment can be worked out with a neighbor who has a similar farm situation. Generally, the farmer tries to hold his work day to ten hours and to avoid Sunday field work. But he will work longer hours for short periods and on Sundays in an emergency.

If this farmer were to buy enough new equipment in 1958 machinery prices to handle satisfactorily all field operations without risking weather damage to more than half of his hay crop in the least favorable years, his investment in machinery and power would be $21,000.[1/]

To equip the farm to do the different tasks satisfactorily in the days available in the average year and to have a chance of getting half of the hay stored without excessive weather damage in the average season would require a machinery investment of $14,700 if purchased new.[2/]

An examination of the tables in the preceding pages indicates that only slightly less time is available and slightly more capacity would be needed to do the work 16 years out of the 20 analyzed than in the average year. However, in the remaining four years the favorable days for most operations dropped sharply. (See days available in worst year, Table VIII, Page 16) Thus, greater capacity, more units, and much longer working hours would be needed to get the job done. The economic desirability of carrying enough equipment to do the job in the least favorable year at current equipment and crop prices is questionable. This is true for the farmers

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1/ Does not include an estimate of cost of equipment such as manure spreader, feed - preparation equipment, movable feeders, waterers, hog houses, etc. or trucks.

2/ Ibid.

with ample capital as well as for those who retain their old machines or purchase used ones to provide the necessary reserve for the extreme situation.

The procedure used to arrive at these estimates of equipment needs, and the one that the individual farmer may use in deciding upon the level to equip his farm in terms of being able to do the job under varying climatic restrictions, follows:

The first step is to list the major tasks to be performed. A summary of the major field operations to be accomplished on the farm used in the illustration is:

Plowing sodland for corn	50 acres
Plowing bare or stalk land for corn and beans	50 acres
Oats land to be fitted and seeded	25 acres
Corn and bean land to be fitted and planted	100 acres
Corn and beans to be hoed and cultivated	100 acres
Wheat and oats to be combined	50 acres
First cutting hay	25 acres, 40 tons
Second cutting hay	15 acres, 12 tons
Third cutting hay	15 acres, 9 tons
Straw baled	25 acres, 25 tons
Wheat land to be fitted and seeded	25 acres
Soybeans to be combined	25 acres
Corn to be picked	75 acres

The second step is to determine the size of equipment or method that will get the task done in the time available with the labor force. This can be accomplished by employing the formula --

$$\frac{\text{Size of individual task}}{\text{Hours available for doing the task}} = \text{Amount to be accomplished per hour}$$

$$\frac{\text{Amount to be accomplished per hour}}{\text{Number of units of the machine that there is labor available to operate}} = \text{Amount to be accomplished per machine per hour}$$

The hours available for doing the task are limited both by the weather and by the time that must be spent on chores and other field operations during the same period. For instance, between March 21 and April 30, the study

indicates there was an average of 14.5 days, including Sundays, favorable for plowing on average-drained sodland; with Sundays omitted, there were 12 5 days. If this were the only task to be done on the 12.5 days, the 50 acres of sodland could be plowed easily with a small tractor and plow However, some of the hours will be spent on livestock chores, the 25 acres to be sowed to oats will need to be fitted and seeded, 50 acres of stalk land will need to be plowed, and if possible, a little time in April will be spent in preliminary soil fitting.

Each task must first be considered separately. Then the time needed for each of the several tasks to be done between March 21 and April 30 must be added to see if all can be accomplished in the days with favorable soil and weather. If not, the size or number of machines or both must be increased until the total time required comes within the days with favorable soil and weather conditions. When the labor force cannot be easily expanded, a larger unit of equipment and power must be employed. If labor is available to operate two or more units,, smaller and more machines and power units can be employed to get the jobs done.

If the farmer undertakes to equip himself to get all of the jobs done in the least favorable years, very large units must be employed Often the tasks can only be completed by hiring additional labor to permit the use of two or more units simultaneously. This need can be readily visualized when one considers the fact that the farmer in the illustration could reasonable expect not more than five favorable days between March 21 and April 30 one year in 20 in which to fit and seed 25 acres of oats land and to plow 100 acres of sod and stalk land. Employing the above procedure, the following equipment and power would be needed on this farm to do the work in the average year (12.5 days) with no Sunday field work and in the

worst year (5 days) with Sunday field work:

Table XVII. Equipment and Power Needed If Most of the Tasks Normally Performed Between March 21 and April 30 Were to be Done by One Man

Machines	Under Average Climatic Conditions	In the Least Favorable Climatic Conditions
1 plow	3 - 14"	4 - 14"
1 disc	7'	10'
1 drill	7'	10'
1 tractor	3 plow size	4 plow size
Length of work day in field	10 hours	13.5

Determination of the balance of the equipment required for the average year and for the worst year followed the same procedure. In the case of meadow crop harvest, there were both the problems of size of machine (baler or chopper) and the curing procedure to be employed.

Conventional field curing would offer the possibility of getting half of the hay in without excessive damage half of the years. However, if he were desirous of getting half of it harvested without serious weather damage in the least favorable seasons, he would need to use a field hay conditioner or mow drying equipment. Following this decision, the size of the baler or chopper and the capacity of drying equipment would be decided upon in much the same manner as used in the case of soil fitting equipment.

SUMMARY

1. In four years out of five, there were slightly more than one third of the days (including Sundays) between March 21 and July 15 when the soil on average drained land was found to be suitable for soil working operations.

2. In the least favorable years, there were approximately 60% more days when conditions were favorable for soil working operations with good drainage than with poor.

3. During March and April, the season for plowing and sowing oats, climatic conditions in bad years reduced the time available on poorly drained soils to half that available on soils with good drainage.

4. In years when the climatic conditions were most favorable for performing soil working operations, the difference in the number of favorable days between good, fair, and poorly drained soils was small.

5. Approximately one day in three could be classed as good for drying hay during the first and second cutting periods. In the least favorable periods, the number of good drying days dropped to as few as one in five.

6. More important than the number of good drying days is the number of consecutively favorable drying days since more than one favorable day is necessary for a satisfactory cure to take place. There was an average of six periods during June when drying conditions were such that meadow cut on the first day could have been stored two days later. Four years out of the 20, the number of favorable periods dropped to four or lower.

7. When a stem crusher or hay crimper was used, there was an average of 12 periods in June when meadow cut one day could have been stored either one or two days after cutting. In four years of the 20, the number of favorable periods dropped to nine or lower.

8. Four years out of five the minimum number of days in which small grain could be combined was found to be six days and four half days.

9. A minimum of five days and three half days was found to be available for combining soybeans four years out of five during the period September 26-October 16, and five days during the period October 17-November 6.

10. Approximately two out of three days were found to be favorable for corn picking four years out of five between October 15 and November 15.

Table XVIII. Days Available on Average Drained Land to do the Common Field Crop Operations As Indicated By this Study

Operation	Days Available		
	Average Year	16 Years Out of 20	Worst Year
Plow Sodland	14.5	12.5	5 0
Plow Bare or Stalk Land	12.0	8 5	2 5
Seeding Oats Including Soil Preparation	8 0	5.5	1.5
Soil Fitting Preceding Final Seedbed Preparation and Planting	8.0	2.5	0.0
Seedbed Preparation and Planting Corn and Beans	13.5	10.0	7.0
Cultivating Corn and Beans	15.0	12.0	9 5
Fall Seeding Small Grain Including Soil Preparation	16.0	12.5	11.5
Combining wheat and oats at			
14% moisture or less	9 whole & 2 half days	6 whole & 4 half days	2 whole & 3 half days
16% moisture or less	11 whole & 4 half days	9 whole & 2 half days	5 whole & 2 half days
Combining soybeans Sept 25-Oct 16			
14% moisture or less	10 whole & 3 half days	5 whole & 3 half days	2 whole & 2 half days
16% moisture or less	12 whole & 2 half days	6 whole & 2 half days	4 whole & 2 half days
Combining soybeans Oct 17-Nov 6			
14% moisture or less	8 whole & 3 half days	5 whole days	4 whole & 1 half days
16% moisture or less	9 whole & 2 half days	6 whole & 2 half days	5 whole & 1 half days
Picking Corn Oct 15-Nov 15	21.5	19.5	15.5
Harvesting Meadow	Percent hay in barn three days after day of cutting		
First Cutting			
Conventional curing	48%	32%	36%
Stem crushing	62%	54%	48%
Second Cutting			
Conventional curing	59%	42%	30%
Stem crushing	79%	86% 1/	40%
Third Cutting			
Conventional curing	53%	38%	6%
Stem crushing	67%	44%	31%

1/ In 16 out of 20 years only 47 per cent would have been ready for storage within 2 days after cutting in contrast to 56 per cent in the average year.

CONCLUSIONS

The data on days favorable for performing the field operations analyzed in this study are based on a careful appraisal of the detailed weather reports for the period 1938-1957 kept by the Weather Bureau at Columbus, Ohio. Assumptions based on factual information were used when available. When not, they were based on experience and observations of farmers and others. It is the opinion of the authors that further refinement can be made as more factual information on the rate of drying following unfavorable weather becomes available. However, further refinement is not expected to sufficiently alter the days available to upset farm labor and equipment plans based on the findings reported in this study.

On many farms with soil drainage problems which greatly add to the limiting effect of climate, expenditures for improving the drainage should be given consideration along with those for more and larger equipment as a means of getting the work done in the favorable days available

Table I. A Comparison of the Period Studied, 1938-1957, with the period, 1906-1957 for Monthly Rainfall and 1911-1957 for Days with .01 Inch or More of Rain

	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.
				(inches of rainfall)					
52-year average	3.32	3.07	3.50	3.46	3.61	3.13	2.51	2.35	2.63
20-year average	3.11	3.30	3.32	3.59	3.61	2.94	2.49	1.91	2.29
Lowest in 52 years	.28	.95	.33	96	.49	.33	.42	.10	.18
Lowest in 20 years	.61	1.72	33	1.79	.49	.49	.74	.25	.97
Highest in 52 years	8.09	6.31	6.95	7.25	7.05	7.01	5.98	5.33	6.19
Highest in 20 years	8.08	6.31	5.41	7.25	7.05	5.18	5.40	5.24	4.92
				(days with .01 inch or more of rain)					
47-year average	13.4	12.8	11.7	11.0	10.0	9.3	8.7	8.8	10.7
20-year average	13.3	13.5	12.5	11.6	10.0	7.9	7.8	7.6	10.8
Lowest in 47 years	8	7	7	5	4	3	4	2	4
Lowest in 20 years	10	7	7	8	4	3	4	3	6
Highest in 47 years	17	20	19	18	15	17	14	18	17
Highest in 20 years	16	19	18	15	13	14	13	18	15

Table II. Mean Monthly Precipitation for the 10 Divisions of Ohio and for Columbus for the 9-Month Period, March-November, 1931-1955

Division of state	March	April	May	June	July	August	September	October	November	Nine month total
Northwest	3.05	3.20	3.60	3 99	3.14	2.72	2 83	2.55	2 27	27.5
North Central	3.02	3.14	3.45	3 95	3.14	3.12	2.80	2.35	2 25	27.2
Northeast	3.27	3.35	3.61	3 57	3 45	3.19	2.95	2.30	2.58	28.9
West Central	3.40	3.32	3.59	4.19	3 42	3.14	3.05	2.54	2.45	29.1
Central	3 59	3.60	3.65	4.16	3.77	3 25	2.74	2.18	2.55	29.5
Central hills	3.42	3.25	3 61	4.17	3 77	3.54	2.83	2.30	2 45	29.4
Northeast hills	3.58	3.40	3.60	4.01	4.01	3.43	2.93	2.56	2 52	30.1
Southwest	4.21	3.64	3.75	4.16	3.57	3.15	2.97	2.32	2.92	30.7
South Central	4.36	3 59	3.93	4.10	4.23	3.67	2.85	2.09	2.67	31.6
Southeast	3.75	3.47	3.91	4.28	4.17	3.77	2.85	2.20	2.56	31.0
Columbus	3.11	3.30	3.32	3.59	3.61	2.94	2.49	1.91	2 29	26.8

Table III Mean Monthly Temperature for the Ten Divisions of Ohio and for Columbus for the 9-Month Period, March-November, 1931-1955

Division of state	March	April	May	June	July	Aug	Sept	Oct	Nov
Northwest	3 .3	48.6	60.0	70.6	74.5	72.5	65 4	54.2	40.5
North Central	37.7	48.4	59.8	70.3	74.3	72.3	65.7	54.7	41.4
Northeast	36.8	47.7	58.9	68.8	72.8	71 1	64 6	53.9	41.1
West Central	39.1	49.8	60.8	70.8	74.5	72.5	65.7	54.5	41.2
Central	40.4	50.8	61.7	71.4	74.8	73.0	66.3	55.3	42.0
Central hills	38.0	48.6	59.7	69.5	73.1	71.3	64.7	53.8	40 6
Northeast hills	38.5	49.1	60.0	69.3	72.8	71.1	64.5	53 6	41 1
Southwest	42.7	51.2	63.1	72.5	75 9	74.2	67 5	58.5	43 0
South Central	44.2	54.4	64 1	73.0	76 1	74.6	68.2	57 0	44 5
Southeast	41.6	52.0	62 3	71.3	74.5	72.9	66.5	55.7	42.9
Columbus	40.9	51.5	62.3	72.6	76 3	74 4	67.6	56 3	42.9

Table IV. Days with 0.01 Inch or More of Rain[1/]

Station[2/]	No. of Years[3/]	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Nine month total
Napoleon	35	8	9	11	9	8	8	8	7	7	75
Norwalk	35	10	11	12	10	10	9	9	8	8	87
Hiram	35	11	11	11	10	10	9	9	9	11	91
Greenville	35	10	11	12	11	9	8	8	8	8	85
Columbus	51	14	12	12	12	11	10	9	9	11	100
Wooster	44	13	12	13	12	10	9	9	9	11	97
Cadiz	25	12	11	11	10	10	9	7	9	10	89
Hillsboro	28	10	11	10	10	9	9	6	7	9	81
Ironton	35	12	11	11	11	11	9	7	7	9	88
McConnelsville	45	12	12	12	12	11	9	8	9	10	95

1/ Source: Climate of Ohio by W H. Alexander and C A. Patton, Ohio Agricultural Experiment Station, Wooster, Ohio. Bulletin 445, 1929.

2/ A station was selected in each of the 10 districts to represent that district

3/ Number of years indicated is the number prior to 1929 for which this record was available

Table V. Days Analyzed as Favorable for Soil Working Operations on Average Drained Soils in Central Ohio by Selected Periods and by Years, 1938-1957

Year	March 21-31	April 1-30	May 1-31	June 1-30	July 1-15	March 21-July 15
1957	5.0	5.0	12.0	11.5	10.0	43.5
56	2.0	6.5	6.5	14.0	7.5	36.5
55	0.0	11.5	13 0	14.5	6.5	45.5
54	1.0	6.0	18.0	17.0	11.0	53.0
53	8.5	12.5	15.0	22.0	9.5	67.5
52	3.0	7.0	11.5	19.0	7.5	48.0
51	2.0	8.5	13.5	12.0	8.0	44.0
50	3.0	8.0	20.0	18.5	8.5	58.0
49	2.0	13.0	18.5	16.0	11.5	61.0
48	1.0	11.5	16.0	14.5	8.5	51.5
47	2.5	7.0	6.0	12.5	6.0	34.0
46	6.0	16.5	9.0	11.0	12.5	55.0
45	0.0	7.5	13.5	15.5	8 5	45.0
44	0.0	6.0	12.5	19.5	12.5	50.5
43	1.0	8.0	9.5	13 5	3.5	35.5
42	4.5	12.5	12.0	17.5	7.0	53.5
41	7.0	13.5	18.5	9.0	10.5	58.5
40	1 0	1.5	13.0	8.0	13.0	36.5
39	5.5	5.0	26.0	6.5	10.0	53.0
1938	1.0	11.0	13.0	19.0	6.0	50.0
Average	2.8	8.9	13.9	14.5	8.9	49.0
Worst	0.0	1.5	6.0	6.5	3.5	34.0
Best	8.5	16.5	26.0	22.0	13.0	67.5
Minimum 16 out of 20 years	1.0	6.0	11.5	11.5	7.0	43.5

Table VI. Days Analyzed as Favorable for Soil Working Operations on Poorly Drained Soils in Central Ohio by Selected Periods and by Years, 1938-1957

Year	March 21-31	April 1-30	May 1-31	June 1-30	July 1-15	March 21-July 15
1957	4.0	2.5	11.0	8.5	9.0	35.0
56	0.5	4.0	4.5	11.0	6.5	26.5
55	0.0	6.5	12.0	13.0	5.5	37.0
54	0.0	4.0	17.0	16.0	10.5	47.5
53	8.5	8.5	14.0	21.0	8.0	60.0
52	1.0	5.5	10.5	18.0	6.0	41.0
51	0.0	6.0	10.5	11.5	7 0	35.0
50	2.0	7.0	18.0	17.0	8.5	52.5
49	1.0	11.5	17 0	13.0	11.5	54.0
48	0.0	7.5	11.5	14.5	8.0	41.5
47	0.5	6.5	3 0	10.0	6.0	26.0
46	3.0	15.0	4 5	8.0	13.0	43 5
45	0.0	7.0	12.0	14.0	8.0	41.0
44	0.0	3.0	8.0	18.0	12.5	41.5
43	0.0	5.5	7.0	11.0	3.5	27.0
42	4.0	11.5	8.5	13.5	5.0	42.5
41	7.0	11.5	16.5	7.5	10.5	53.0
40	0.0	0.0	12.5	4 5	12.0	29.0
39	4.5	3.0	26.0	4.0	10.0	47.5
1938	0.0	8.0	11 5	15.5	5.0	40.0
Average	1.8	6.7	11.8	12 5	8.3	41.5
Worst	0.0	0.0	3 0	4.0	3 5	26.0
Best	8.5	15.0	26 0	21.0	13 0	60.0
Minimum 16 out of 20 years	0.0	4.0	8.0	8.5	6.0	35.0

Table VII. Days Analyzed as Favorable for Soil Working Operations on Well Drained Soils in Central Ohio by Selected Periods and by Years, 1938-1957

Year	March 21-31	April 1-30	May 1-31	June 1-30	July 1-15	March 21-July 15
1957	6.0	7.0	13.5	12.5	11.5	50.5
56	3.5	8.5	8.5	16.0	8.5	45.0
55	0.0	15.0	15.5	18.0	7.0	55.5
54	2.0	7.5	20.0	19.0	11.5	60.0
53	8.5	14.0	18.0	23.0	10.5	74.0
52	3.0	10.5	13.5	20.0	9.0	56.0
51	3.0	11.5	16.0	13.5	9.5	53.5
50	5.0	10.0	20.0	19.0	9.5	63.5
49	2.0	14.0	19.5	17.0	11.5	64.0
48	2.5	14.0	17.0	17.5	9.0	60.0
47	3.0	9.5	8.5	14.5	6.0	41.5
46	6.5	18.0	11.5	12.5	13.0	61.5
45	1.0	11.5	16.5	15.5	9.5	54.0
44	0.0	8.0	14.0	20.5	12.5	55.0
43	2.0	10.0	10.5	15.0	4.5	42.0
42	4.5	15.0	13.0	17.0	7.5	57.0
41	7.5	15.5	20.5	10.0	10.5	64.0
40	1.0	4.0	13.0	12.0	13.0	43.0
39	5.5	7.0	26.0	9.0	10.5	58.0
1938	2.5	13.0	13.5	20.5	7.5	57.0
Average	3.4	11.2	15.4	16.1	9.6	55.7
Worst	0.0	4.0	8.5	9.0	4.5	41.5
Best	8.5	18.0	26.0	23.0	13.0	74.0
Minimum 80% of years	2.0	8.0	13.0	12.5	7.5	50.5

Table VIII. Hay Drying Conditions 6 a.m -6 p.m Prevailing during the Periods for First, Second, and Third Cutting by Years, 1938-1957

Year	Drying Conditions between 6 a.m. and 6 p.m. by days											
	First Cutting, June 1-30				Second Cutting, July 15-Aug. 15				Third Cutting, Sept. 1-20			
	Good	Fair	Poor	Rain 1/	Good	Fair	Poor	Rain 1/	Good	Fair	Poor	Rain 1/
Average	10.9	5.5	6.3	7.3	12.7	8.2	6.0	5.1	8.1	4.0	4.7	3 2
1957	10	5	7	8	14	5	9	4	4	5	6	5
56	12	5	5	8	7	9	10	6	5	7	4	4
55	12	4	5	9	15	5	9	3	14	3	2	1
54	13	4	6	7	13	6	5	8	8	3	6	3
53	11	8	5	6	15	8	3	6	8	3	4	5
52	16	5	4	5	14	8	5	5	11	4	3	2
51	9	4	11	6	12	11	4	5	8	6	3	3
50	8	8	6	8	12	9	7	4	5	2	9	4
49	17	4	3	6	13	9	2	8	7	5	5	3
48	13	3	6	8	14	5	5	8	12	3	3	2
47	8	8	11	3	9	7	10	6	10	1	5	4
46	10	8	6	6	12	9	4	7	14	1	2	3
45	6	8	6	10	9	11	10	2	7	5	3	5
44	13	7	4	6	21	4	3	4	13	3	2	2
43	12	6	5	7	14	10	3	5	6	3	10	1
42	6	9	8	7	6	9	10	7	2	5	8	5
41	13	2	4	11	17	10	2	3	9	3	3	5
40	9	3	10	8	14	9	6	3	6	6	7	1
39	9	3	7	11	11	10	6	5	9	7	2	2
1938	11	6	7	6	13	10	6	3	4	4	8	4

1/ One-hundredth inch or more.

Table IX. Drying Conditions for Small Grain, July 5-31 by Years, 1938-1957

Year	Drying condition on days without rain between 6 a.m. and 6 p.m.			Days with rain[1]	
	Good	Fair	Poor	Between 6 a.m. and 6 p.m.	During the 24 hrs.
Average	11.2	5.9	4.3	5.5	8.8
1957	14	5	4	4	6
1956	5	6	10	6	10
1955	12	4	6	5	10
1954	15	5	2	5	8
1953	16	5	2	4	5
1952	15	5	3	4	6
1951	9	5	10	3	7
1950	10	7	4	6	9
1949	11	8	2	6	10
1948	12	4	3	8	10
1947	5	6	6	10	13
1946	12	4	4	7	11
1945	11	7	5	4	9
1944	16	3	5	3	4
1943	7	8	4	8	12
1942	5	10	3	9	12
1941	15	6	2	4	10
1940	13	7	5	2	6
1939	9	6	5	7	10
1938	13	7	2	5	9

[1] One-hundreth inch or more of rainfall.

Table X. Drying Conditions Prevailing during Two Harvesting Periods for Soybeans by Years, 1938-1957

	September 26-October 16					October 17-November 6				
	Drying condition on days without rain between 6 a.m. and 6 p.m			Days with rain[1]		Drying condition on days without rain between 6 a m and 6 p.m.			Days with rain[1]	
	Good days	Fair days	Poor days	Between 6 a.m. & 6 p m.	During the 24 hrs.	Good days	Fair days	Poor days	Between 6 a.m. & 6 p.m.	During the 24 hrs.
Av.	9.0	5.2	3.5	3.3	4.5	7.6	3.7	5 8	3.9	5.9
1957	6	8	6	1	1	2	5	9	5	9
56	11	9	0	1	3	9	3	4	5	5
55	6	6	3	6	9	5	5	5	5	7
54	3	5	5	8	12	5	2	7	7	12
53	15	2	2	2	2	11	4	4	2	3
52	7	6	5	3	3	11	5	5	0	2
51	10	8	2	1	2	5	2	8	6	9
50	7	6	4	4	6	9	3	5	4	4
49	12	2	3	4	6	6	6	9	0	3
48	4	5	8	4	6	4	10	2	5	7
47	11	9	1	0	1	8	0	7	6	10
46	9	7	3	2	3	12	2	4	3	6
45	5	5	8	3	6	10	2	6	3	7
44	3	7	6	5	7	13	5	2	1	1
43	18	1	0	2	3	2	4	13	2	5
42	9	4	3	5	5	4	5	6	6	6
41	5	3	4	9	9	7	2	6	6	7
40	11	4	3	3	3	9	4	2	6	6
39	11	5	3	2	3	3	3	10	3	3
38	16	2	2	1	1	16	2	1	2	6

[1] One-hundredth inch or more of rainfall.