THE CLIMATE OF MICHIGAN AND ITS RELATION TO AGRICULTURE

THESIS FOR DEGREE OF M. S.

DEWEY ALSDORF SEELEY

1917

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OUTLINE.

OUTLINE (Continued.)

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Dewey A. Seeley.

INTRODUCTION.

The whole realm of human activities and pursuits is affected by weather conditions, but none more vitally than Agriculture. The average of the weather conditions makes up climate, and an accurate description of the climate of any section can be used as a guide in determining the suitability of any section for particular crops, provided soil conditions are right for those crops.

It is the purpose of this paper to describe the climate of the state of Michigan and state its suitability to various crops. It will be necessary to enquire into the factors that determine climate, at the outset, in order to understand the peculiarities that will be noted in the climatic conditions in different sections of this state.

PART I
FACTORS CONTROLLING CLIMATE

Latitude, altitude, environmental surroundings, and the location of a place relative to the path of storms, each has a decided influence on climate. Without going into detail with regard to each of these it will be sufficient to notice that the distance north or south of the equator, other things being equal, determines the temperature of a locality because the sun's rays strike the earth at a greater and greater angle with increasing latitude. In round numbers the average annual temperature decreases about one degree with each 100 miles north or south of the equator.

Altitude, or height above sea level, has an effect on temperature analogous to that of latitude. On the average the temperature decreases about one degree Fahrenheit with each rise of 300 feet in height. As a result the summits of high mountains are continually snow-capped throughout the year, even in the tropics. On the other hand slight elevations of ground which provide good air drainage are not subject to the extremes of low temperature or killing frosts to the extent that low, undrained areas are, because the cold air, being heavier than warmer air, drains off from the hill sides into the swales. Low ground is sometimes colder by eight or ten degrees than higher ground near by.

Elevated sections usually receive more rainfall than lower areas, especially on the slope from which the prevailing winds blow, because the currents of air which are forced to rise up the slope, expand and cool as they rise, thereby producing greater condensation and precipitation. It will be noted later that the effect of elevation on rainfall is noticeable even in Michigan where the differences in height above sea level are comparatively slight.

The third factor in the control of climate, that of environmental conditions, is one which is particularly important in Michigan. The effect of the Great Lakes is marked, especially along Lakes Michigan and Superior, causing wide departures in temperature and other climatic conditions, between those sections and other regions of the same latitude and altitude. Large bodies of water heat much more slowly in summer and cool correspondingly slowly in winter, than adjoining land areas, so that the Great Lakes are cool in summer and warm in winter, compared with the temperature of interior land areas. This is due to the fact that from five to seven times the amount of heat necessary to raise the temperature of a given weight of soil one degree is required to warm the same weight of water an equal amount. The fact that considerable heat from the sun's rays is used up in evaporating some of the surface water also retards rapid heating. The fact that the water is usually in motion and any heating at the surface is transferred to other regions, whereas in the case of the soil this mixing does not take place and the surface becomes superheated, is another reason why the land is warmer than water areas in summer. Furthermore insolation is transmitted and conducted through water much more readily than through soil, which is an additional cause of super-heating of the surface of latter compared to the former. As a result of these various factors actual tests of temperature of the water in the Great Lakes in mid-summer show readings as much as 30°F. to 40°F. lower than soil temperatures taken near the surface of the ground in the interior of the state at the same time. The prevailing westerly winds blowing across these wide expanses of comparatively cool water in summer are greatly ruduced in temperature and reach the Michigan shore as cool, refreshing breezes.

The great volume of heat that is stored up in the lakes during the summer is held well into the winter season. In fact only in the very coldest winters does the water freeze solidly across , and then only for short periods. Therefore the extremely cold northwest winds which usher in typical cold waves in winter, are decidedly tempered in crossing the comparatively warm water and strike the eastern and southern coasts greatly increased in temperature.

The fourth factor influencing climate is the location of the region relative to the normal storm path. Storms are areas of low atmospheric pressure which travel across the continents and oceans in a general west to east direction, sometimes retaining their identity entirely around the world. On account of the fact that the winds blow spirally inward toward the center of these great low pressure areas, as they progress eastward, they are called "Cyclones". They are great atmospheric whirls, usually covering sveral states in extent, and travel easterly from 200 to 2000 miles per day. The paths or routes that these disturbances travel are quite well defined. The majority of them move somewhat southeastward over the western half of the country, changing their course to northeastward when they reach a point a few hundred miles this side of the Rocky Mountains. The further south a storm goes the more pronounced is the turn to the northward in the middle-western states.

As a result the majority of storms pass the region of the Great Lakes and drift eastward out the St. Lawrence valley. These storm areas bring with them the typical change to warmer and unsettled weather, with rain or snow, according to the season.

Following these disturbances areas of high pressure or anti-cyclones usually arrive, bringing with them just the opposite sort of weather. Most of these formations first appear on the weather map in the far Northwest whence they move southeastward, many of them toward the Great Lakes. As the air flows out away from these areas, as cold, icy blasts in winter, the wind is northwest in advance of one of these anti-cyclones, sometimes reaching the required severity to be termed a "Cold wave". Now Michigan is in the direct path of the majority of both the cyclones and anti-cyclones, and the weather therefore swings back and forth from one type to the other in irregular intervals of three to five days. Rainfall is more or less evenly distributed throughout the year and monotonous periods of extreme conditions of any kind are infrequent and short in duration. On the other hand regions remote from these storm paths are not so evenly watered and do not experience the fluctuating conditions of this section.

PART II. THE CLIMATE OF MICHIGAN.

Having outlined the factors which control climate in general the peculiarities of the climate of Michigan will be more easily accounted for. The various elements which make up climate, i.e. temperature, precipitation, cloudiness, wind and humidity, will be taken up separately as they are found in this state and described in order.

Michigan lies almost entirely between latitudes 42° and 47° N. ~~latitude~~, and is therefore about the same distance north of the equator as France, Switzerland, northern Italy, Austria and the Balkan States. Its climate is somewhat colder that the first three countries named but about the same in temperature as Austria and the northern portion of the Balkans. The ocean currents tend to cause milder weather in the three former. The average annual temperature ranges from about 39°F in the coldest portions of the upper peninsula to 49°F. in the southern tier of counties. Chart II shows the isothermal lines for the year, and they indicate clearly the decrease in temperature with increase in latitude. The effect of altitude can be noticed by studying the elevations shown in Chart I in connection with the annual temperatures. The following will serve to illustrate this effect:

Station.	Elevation, feet.	Mean annual temperature, degrees F.
Humboldt, Marquette Co.	1536	36.9
Newberry, Luce Co.	773	39.3
Difference	763	2.4
Ann Arbor, Washtenaw, Co.	930	47.1
Eloise, Wayne, Co.	640	48.1
Difference	290	1.0
Hillsdale, Hillsdale Co.	1150	47.1
Adrian, Lenawee Co.	770	48.5
Difference	380	1.4

Each pair of stations was selected to show the true effect of elevation alone, other influences such as

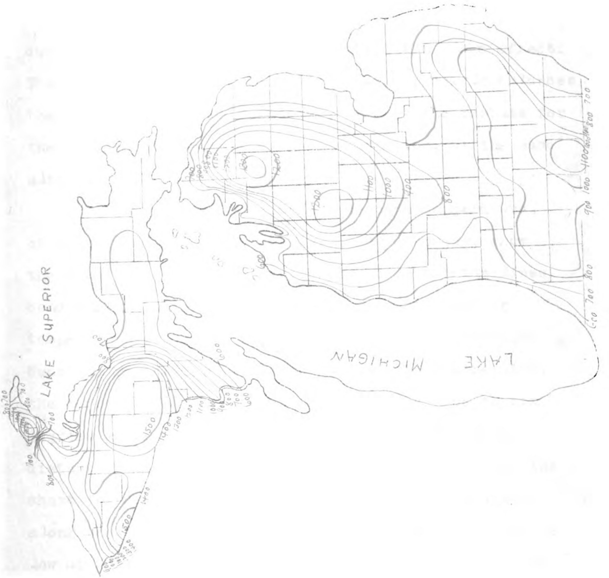


CHART I,-Elevation, in feet.

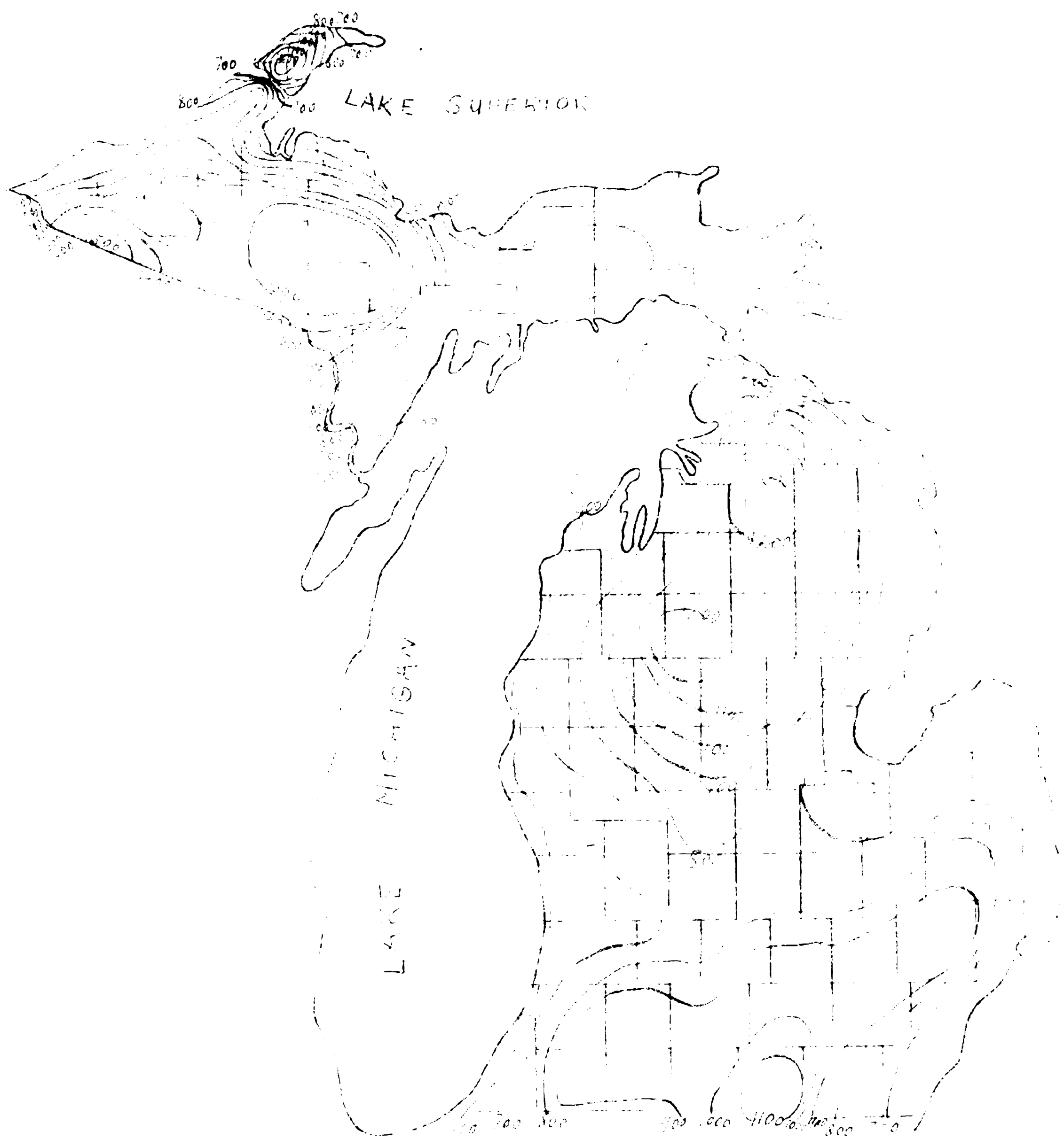


CHART I,-Elevation, in feet.

latitude, distance from lake etc. being about the same for both stations in each pair.

The effect of the lakes on the mean annual temperatur e is evident, yet not as pronounced as it is in the case of either summer or winter temperatures. Chart II shows that the temperature is lower in the interior of the state than it is along the lake shores, but this is probab ly due more to the influence of elevation than lake effect. The cooling effect of the lakes in summer near ly balances the warming influence in winter, leaving the results for the year about the same as in the interior, at the same altitude.

Charts III and IV, showing the mean temperature of Michigan for January and July, respectively, show the lake effect more clearly. In the former the lines bend sharply northward along Lake Michigan, as the temperature is higher on the lake shore. In the Lake Superior region the isotherms parallel the shore line, the temperature of the coast cities being four to six degrees warmer than interior points but a few miles distant. Just the opposite conditions are shown on the chart for July. Here the lines bend sharply downward along the Lake Michigan shore, the temperature being as low at South Haven, for example, as at West Branch, an interior station more than 100 miles farther north.

The most striking illustration of the lake effect is brought out by Charts V and VI. These charts are drawn from data recorded during the very cold month of January, 1912, and the very hot month of July, 1916, the temperatures

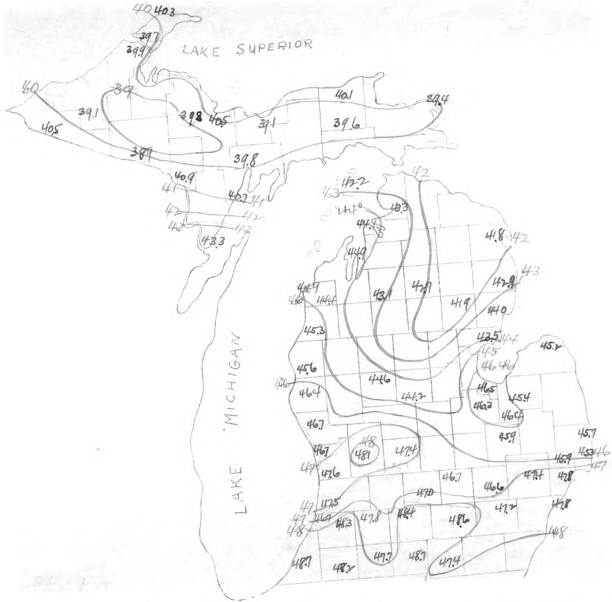


CHART II.-Mean temperature for the year in degrees F.
(Averages for ten years of more at each station.

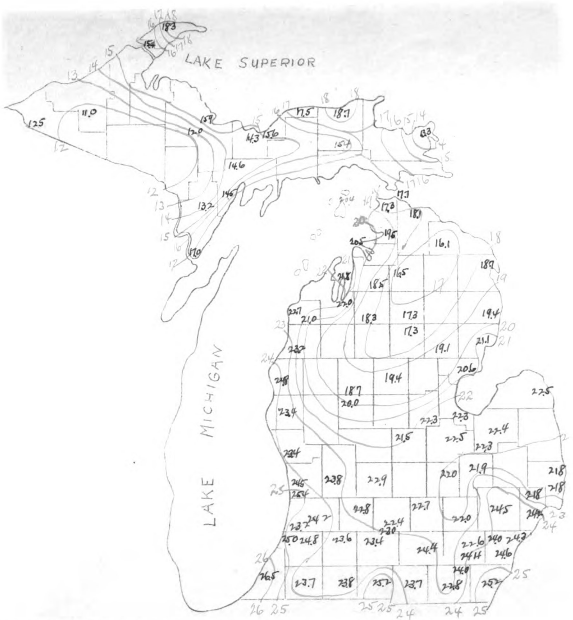


CHART III.-Mean temperature for the month of January.

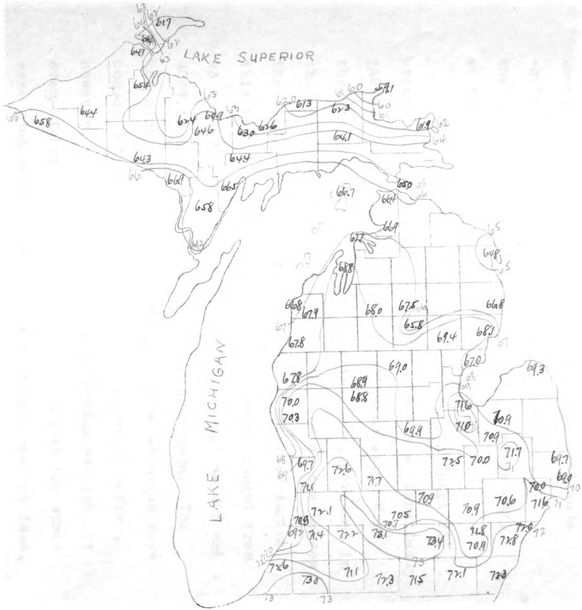


CHART IV.-Mean temperature for the month of July.

used being, respectively, the lowest in January and the highest in July. The moderating effect of all the lakes is shown by Chart V. In the upper peninsula readings as low as -45°F and -46°F were registered in the interior counties, while at Eagle Harbor the north-most station, on the Keweenaw peninsula, the lowest reached was -17°F. In the lower peninsula -39°F. was recorded at Gaylord, Otsego Co., but the lowest at Old Mission, on Grand Traverse Bay, at the same latitude, was -7°F.

The July maximum temperature chart,(Chart VI), brings out the cooling effect of the Lakes, especially Lake Michigan during extremely hot weather. Here the isotherms are crowded close together, parallel to the shore line, indicating a rapid rise as one leaves the lake. The highest temperature recorded during this month of almost unprecedented heat, ranged from 93 to 96°F. on the lake shore, to as high as 105 and 106F. in the interior of the lower peninsula. The hot southwest winds in traversing Lake Michigan were cooled 10° or more. On the Lake Superior shore, however, temperatures were ~~practically~~ as high or even higher, than farther inland, because the winds were southwesterly and the lake effect was not felt, while inland the greater elevation of the land tended to reduce the temperature somewhat.

To further illustrate the effect of the Great Lakes on temperature five tables are reproduced, herewith, as follows: The mean monthly temperature, mean monthly

CHART V.-The lowest temperatures recorded during the month of January, 1912, one of the codest months on record in Michigan.

CHART VI.-The highest temperatures recorded during the month of July, 1916, one of the hottest months on record in Michigan.

maximum temperature, mean monthly minimum temperature, absolute maximum and absolute minimum temperatures at Grand Haven, Michigan, Milwaukee, Wis., and the average of such temperatures at five cities in South Dakota, Wisconsin and Iowa, having the same latitude, as complied by Eshleman 1. The difference in temperature between that at Grand Haven and the average of the five interior stations is noted by means of "+" and "-" signs. It will be noted from Table I that the mean temperature for the year is practically the same for all stations, but that Grand Haven is warmer in winter and colder in summer by several degrees than the western stations, and slightly warmer in winter and cooler in summer than Milwaukee, because it is on the windward side of the lake. Table II gives the average maximum temperature for each month at the several stations and shows a great difference between Grand Haven and the western cities during the summer months, also in the spring and early autumn, Grand Haven being cooler during this period by 6 to 10°F. The average minimum temperatures reached daily for the various months are tabulated in Table III, bringing out the fact that extreme cold is not felt at Grand Haven as it is in the West, away from the lake. Throughout the winter the difference ranges from 9° to 11°F. But the most pronounced effects are shown in Tables IV and V which give the highest and lowest ever recorded, respectively, each month in the year.

Table I.-Mean monthly temperatures (°F)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Grand Haven	24	24	31	44	55	65	70	68	61	50	38	30	46
Milwaukee	20	22	32	43	54	64	70	69	62	50	36	26	46
Western Stations	18	17	32	48	59	68	73	71	62	50	33	22	46
Difference	+6	+7	-1	-4	-4	-3	-3	-3	-1	0	+5	+8	0

Table II.-Mean monthly maximum temperature (°F.)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Grand Haven	31	29	39	52	63	73	77	76	70	58	45	34	54
Milwaukee	27	30	38	52	63	72	78	76	70	58	43	32	53
Western Stations	29	28	43	61	73	81	87	85	76	64	44	32	59
Difference	+2	+1	-4	-9	-10	-8	-10	-9	-6	-6	+1	+2	-5

Table III.-Mean monthly minimum temperatures (°F.)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Grand Haven	19	16	25	36	45	56	60	59	53	43	32	24	39
Milwaukee	13	15	24	37	45	55	62	61	54	44	30	20	38
Western Stations	9	7	21	36	47	57	61	59	50	38	22	13	35
Difference	+10	+9	+4	0	-2	-1	-1	0	+3	+5	+10	+11	+4

Table IV.-Absolute maximum temperature (°F.)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Grand Haven	61	59	71	84	87	92	94	92	92	82	72	61	94
Milwaukee	61	60	81	86	94	98	100	98	95	88	73	63	100
Western Stations	63	72	84	95	98	104	110	104	103	92	75	65	110
Difference	-2	-13	-13	-11	-11	-12	-16	-12	-11	-10	-3	-4	-16

Table V.-Absolute minimum temperature (°F.)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Grand Haven	-14	-25	-5	9	28	37	40	42	30	20	0	-12	-25
Milwuakee	-25	-24	-8	12	25	38	47	42	30	15	-14	-22	-25
Western Stations	-30	-32	-12	9	28	35	40	37	20	7	-13	-24	-32
Difference	+16	+7	+7	0	0	+2	0	+5	+10	+13	+13	+12	+7

The tables above show the effect of Lake Michigan on the temperature of Grand Haven and Milwaukee. The averages of five stations in South Dakota, Wisconsin and Iowa, having the same latitude as Grand Haven and Milwaukee, were selected for comparison. The "difference" is the departure between the reading at Grand Haven and the average of the five western stations, in each case.

These tables show that the extremes of temperature experienced at inland stations are not felt at Grand Haven, which is a typical lake station.

As already stated the frequent passage of cyclones and anti-cyclones across the lake region causes fluctuating temperature to a greater extent than is found in regions outside the storm path. In the winter season the approach of a storm area from the west is preceded by southerly wind and rising temperature in Michigan, and the high pressure area which follows brings with it a shift of wind to the northwest, with colder weather. In the summer season storm areas which move across the northern portion of the Great Lakes, at a time when the pressure is high over the southeastern states, cause hot waves in this state, but these are usually followed in a day or two by refreshing northerly breezes attending approaching high pressure areas from western Canada. The changeableness of the temperature is therefore one of the noticeable features of the climate of Michigan.

Precipitation.

Rain and snowfall should be next considered. The same four factors which control the temperature of a place also influence, to a greater or less extent, the amount of precipitation. The influence of latitude is not so pronounced on precipitation as on temperature. In fact within the range of latitude found in Michigan no difference in rainfall due to distance from the equator is noticeable.

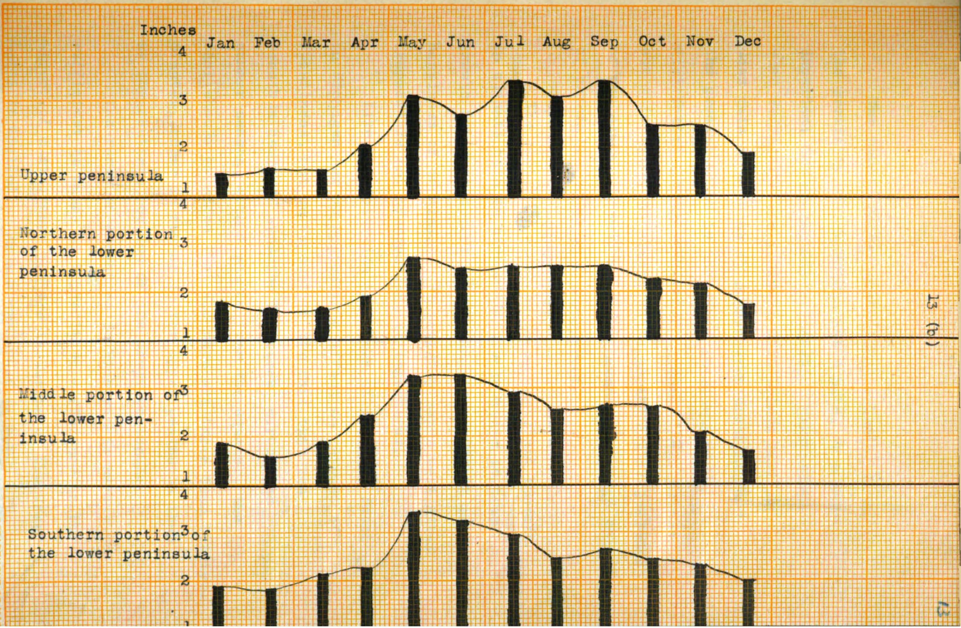
The effect of elevation is noticeable, however, prehaps to a greater extend than on temperature. Chart VII, showing the normal precipitation for the year over the state, if noted in connection with Chart I, giving elevations, reveals the fact that rainfall usually increases with altitude,.as a general rule. This is especially true on the western slope of higher land. For example the heaviest rainfall in the state is in the southern tier of counties, beginning about 25 miles from the Lake, where the elevation begins to increase toward the eastward. In the upper peninsula the most rain falls in the interior counties, where the elevation is greatest. In the elevated regions in the northern portion of the lower peninsula, however, the rainfall is not greater than nearby sections having less altitude.

The Great Lakes undoubtedly increase the rainfall throughout this whole region, but the annual amount of precipitation is not noticeably greater on the immediate lake shores than further inland. Such large bodies of water furnish much vapor to the atmosphere, which is carried upward by convection with each cyclone which passes, is cooled, condensed and precipitated as rain or snow. In the lake region the annual rainfall is over thirty inches, while in the Dakotas it is less than twenty inches,-a difference due partly at least to the lake effect. The reason for even less rainfall

CHART VII,-Annual rainfall in inches. Averages for ten years of more at each station.

immediately along the shores of the lakes, than in some interior sections, may be the fact that the cooler weather near the lakes in summer does not foster the convectional action and local thunderstorms to the extent that the warmer interior regions do. The average number of thunderstorms per year at Grand Haven, Mich. is twenty-six, while at Lansing the average is forty-two. The snowfall is considerably greater near the lakes, however, especially along the southern coast of Lake Superior and the eastern coast of Lake Michigan. In the former section over one hundred inches of snow usually falls each winter, as shown in Chart VIII, Along the shore of Lake Michigan from fifty to sixty inches per year is the average, but in the interior of the state the snowfall totals from thirty to fifty inches annually, in most sections. In the northern portion of the upper peninsula the showfall exceeds one hundred inches annually. This heavy snowfall along the lakes is caused by the passage of the prevailing westerly winds, first over the comparatively warm water of Lakes Michigan and Superior, for distances of sixty to over one hundred miles, causing them to become moisture ladened, and then on coming in contact with the cold land areas along the shore the moisture is condensed and falls as snow almost continually, at least while the winds continue on shore, during the winter season. The ground is usually covered in the Lake Superior region, with one to five feet of snow, from middle autumn to late spring.

CHART VIII.- Average annual snowfall, in inches.


Inches
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
4
3
2
1
Upper peninsula
Northern portion of the lower peninsula
Middle portion of the lower pen- insula
Southern portion of the lower peninsula
DEPARTMENT OF MAT

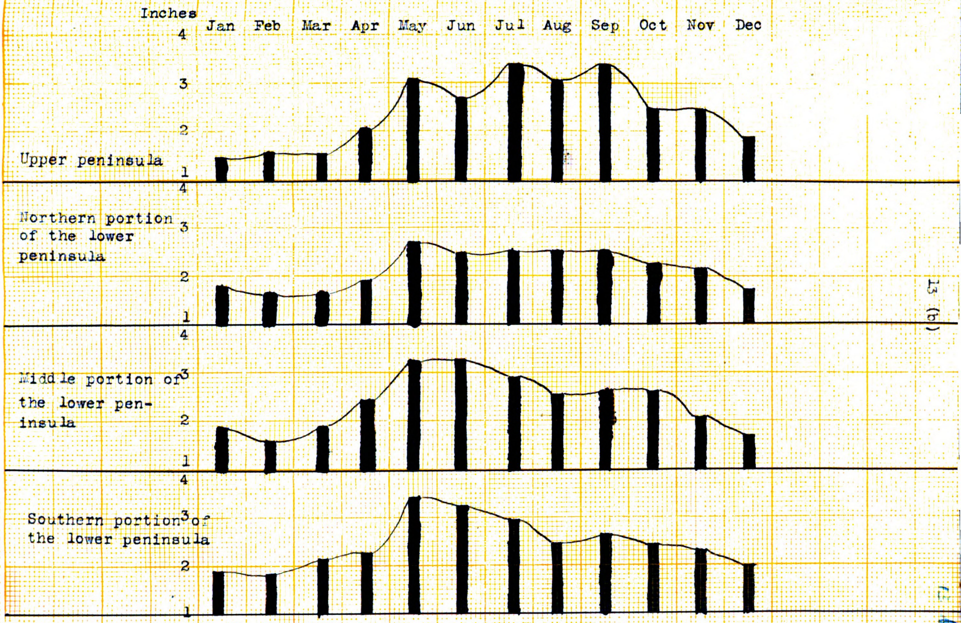


CHART IX,- The distribution of precipitation by months in different sections of the state.

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The fourth factor controlling climate, i. e. the proximity of the normal storm path, is a very important one as regards rainfall. Ordinarily each successive low pressure area brings more or less rain or snow as it passes over Michigan, and the precipitation is therefore ample and well distribtted through the year. Chart IX brings out this matter of distribution in difference portions of the state, as well as graphically showing the amount of rainfall available in each place.

Cloudiness.

The amount of sunshine is an important element in climate both on account of its relation to crop growth and development and the general wellfare and happiness of mankind. It probably ranks next after temperature and precipation, in importance.

Like precipitation the range of latitude found in Michigan has no appreciable affect on amount of cloudiness, but on account of the fact that the possible hours of sunshine increases, during the summer season, with distance from the equator, the fact should be noted that the days are more than thirty minutes longer in summer in the upper peninsula than in the southern portion of the lower peninsula.

The range of elevation in Michigan is hardly sufficient to cause an appreciable difference in the amount of cloudiness but the influence of the Great Lakes is decided. As was explained in connection with

discussion of precipitation, the warm, moist air over the Lakes in winter, is carried land-ward by the prevailing westerly winds, and clouds are continuously formed when the colder land areas are reached, by condensation. The weather is therefore unusually cloudy in Michigan during the late fall and winter months, especially in the western half of the lower peninsula. In fact with the exception of portions of New York state, along the eastern end of Lake Erie, and in the eastern portion of the upper peninsula of Michigan, there is less sunshine along the Lake Michigan shore than in any other section of the country. In January the actual sunshine in western Michigan is less than twenty per cent of the the possible amount.

During the warmer portions of the year, however, the Great Lakes have just the opposite effect. The cool water tends to prevent convection and clouds are not formed to the extend that they are in warmer sections. As a result the amount of sunshine is therefore greater in July, by about ten percent, in western Michigan than it is in Ohio and Indiana.

The alternate passage of areas of high and low pressure over the state results in fluctuating cloudiness. Low areas usually cause more or less cloudiness for one or two days during their approach and passage and these are followed by two or three days of clear weather, as the anti-cyclones pass over. This change from cloudy to clear weather and back again is not noticeable in the

winter season to the extent that it is in summer on account of the almost continuous cloudiness caused by the Lakes. In the summer time the cyclonic and anti-cyclonic formations often become so feeble that they fail to cause the changes in cloudiness and there are long periods of uninterrupted sunshine. These features are clearly shown in Table VI, herewith.

WIND

The wind direction and velocity are important largely on account of their relation to the other climatic elements. The direction of the prevailing winds, for example, is especially important in this state on account of the position ofn the Great Lakes. If they were east instead of west then it would be the Lake Huron shore that would have the more equable climate.

Michigan is, of course, in the region of the prevailing westerly winds. Chart X .. shows the prevailing direction at each observing station in the state. Local influences such as the contour of the land and the proximity of the Lakes causes some deviation from the true west, at some stations. The "land and sea breeze" is pronounced along the lake shores. This is a local wind, blowing on shore in the heat of the day and toward the water at night, due to convection. The air becomes hot and lighter over the land than over the water on a hot summer day, and the cooler and heavier air over the cool water moves in, forcing it upward. Just the opposite action takes

	Days	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Upper peninsula	Rainy	10	8	8	8	11	9	8	8	10	9	10	10	109
	Clear	8	10	12	13	13	14	17	15	12	11	8	7	140
	Partly cloudy	5	6	7	6	7	7	8	8	7	6	6	6	79
	Cloudy	18	12	12	11	11	9	6	8	11	14	16	18	146
Northern portion of lower peninsula	Rainy	9	8	8	8	8	7	7	7	8	8	7	8	93
	Clear	7	9	11	12	14	14	17	15	12	13	8	6	138
	Partly cloudy	6	7	8	7	8	9	8	9	8	7	7	6	90
	Cloudy	18	12	12	11	9	7	6	7	10	11	15	19	137
Central portion of lower peninsula	Rainy	9	7	7	8	9	8	8	7	8	7	7	8	93
	Clear	6	7	9	10	10	13	15	15	12	12	7	5	121
	Partly cloudy	9	9	10	9	12	11	11	11	10	9	9	9	119
	Cloudy	16	12	12	11	9	6	5	5	8	10	14	17	125
Southern portion of lower peninsula	Rainy	10	7	9	9	10	9	8	8	8	7	7	9	101
	Clear	7	8	9	11	12	13	16	15	14	13	9	7	134
	Partly cloudy	6	8	9	8	9	10	10	10	8	8	8	7	101
	Cloudy	18	12	13	11	10	7	5	6	8	10	13	17	130

TABLE VI.- This table shows the number of rainy, clear, partly cloudy and cloudy days in each month and for the year in each of four sections of the state. A "Rainy" day is one with 0.01 inches or more of rain or melted snowfall, a clear days is one with zero to three tenths clouds, a partly cloudy day, four to seven tenths of clouds, and a cloudy day eight to ten tenths overcast.

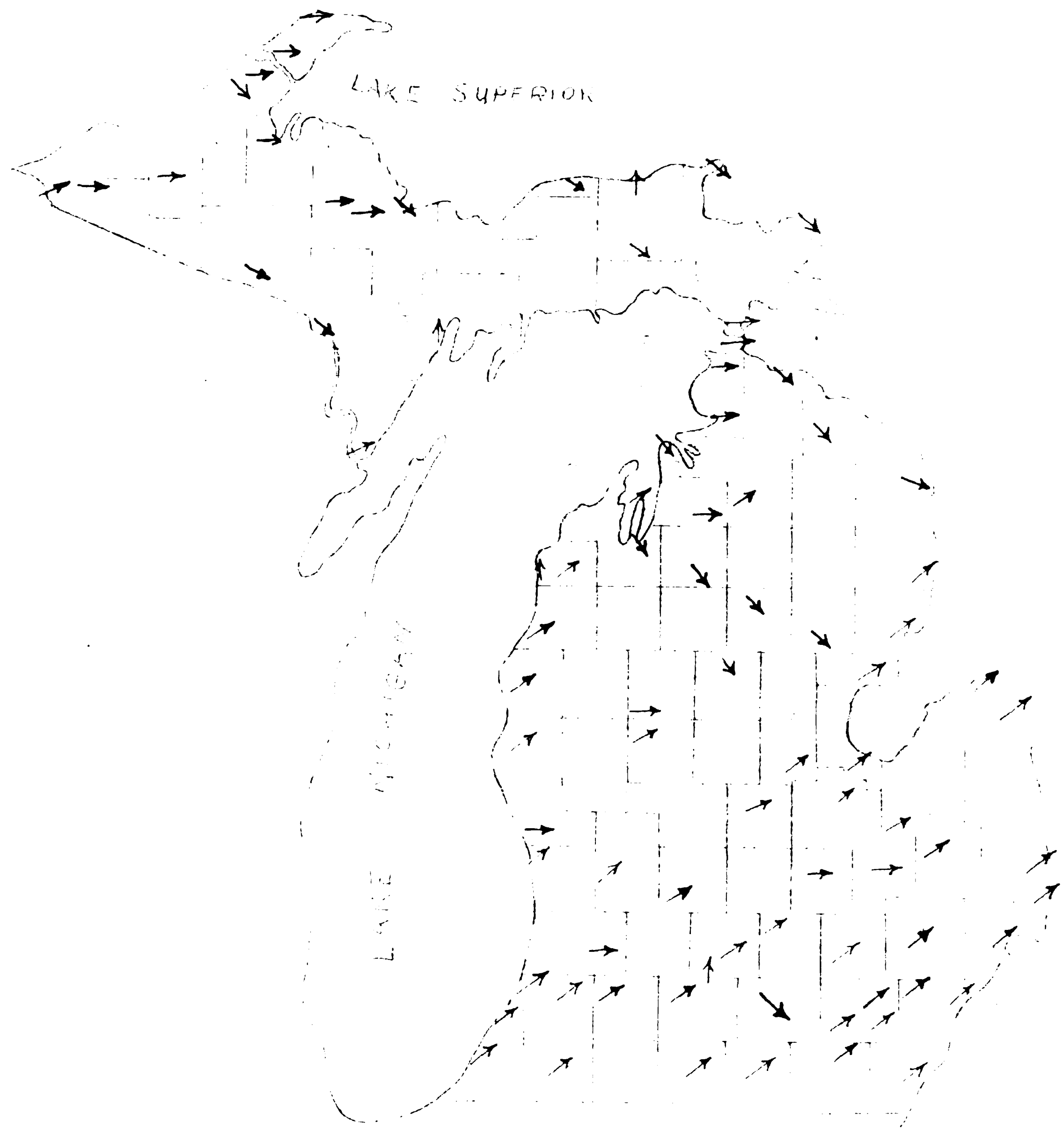


CHART X ,-Prevailing wind direction. Arrows fly with the wind.

place at night, when the land becomes cooler than the lake. These cool, refreshing lake breezes are very welcome on a hot summer afternoon, but in the early spring they are often too cool to be pleasant. The temperature often falls thirty degrees or more within a few minutes when the wind shifts on a warm spring afternoon,and blows in from the cool lake.

As has already been stated the passage of areas of low and high pressure across the Great Lakes region is attended by shifting winds. The currents of air flow spirally inward toward the centers of low barometer, counter-clockwise, while in the high pressure areas the winds blow spirally outward from the center, in a clockwise direction. When a cyclone approaches from the west, therefore, the winds are first southeasterly, shifting around either through east and north, or through south and southwest, depending, of course, on the path the storm takes, changing in the former direction if the storm passes south of the observer, and in the latter direction if the center is to the northward. With the oncoming high area, if it advances from the northwest, the winds are northwesterly. With a good aneroid barometer and wind vane the movement and passage of these atmospheric formations can be determined and followed with interest and profit, for they largely control weather changes.

Humidity.

The amount of moisture in the atmosphere in the form of vapor is important enough to be classed in with the other climatic elements. It is usually expressed in terms of relative humidity, or the per cent of moisture present in the air, compared with the possible amount. The capacity of the air for moisture increases rapidly with the temperature. For example the invisible vapor necessary to saturate air at 40°F. is sufficient to produce a relative humidity of but 50 per cent when the air temperature is increased to 60°F.

Of the four factors which control climate only the last two need to be mentioned here in their relation to humidity, because neither the range of latitude or altitude found in Michigan is sufficent to appreciably change the humidity. But the presence of the large water surfaces of the Great Lakes is an important factor in influencing the humidity, because such surfaces are constantly evaporating water into the atmosphere. The following table will serve to show the effect of the Great Lakes on relative humidity:

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Lansing, Mich.	85	80	74	68	68	68	67	73
Bismark, N.D.	66	67	65	55	54	59	52	49

	Sept.	Oct.	Nov.	Dec.	Year.
Lansing, Mich.	80	81	80	85	76
Bismark, N.D.	52	60	63	67	59

TABLE XI. Relative humidity at Lansing, Mich. and Bismarck, N.D. at 7 p.m., by months and for the year.

Part of the difference in relative humidity between the two stations in the table is probably due to the fact that Bismarck, N.D. is some distance from the normal storm path, while Lansing, Mich. is more directly in the region most frequently traversed by "highs" and "lows". An increase in cloudiness and rainfall, brought about by the passage of low pressure areas, also causes an increase in relative humidity.

Other Phenomena.

There is yet to be considered the occurance of other atmospheric phenomena such as hail, frost, tornadoes, etc. These are more or less destructive to farm crops and their discussion will properly fall in what is to follow. But a word should be said as to their dsitribution and frequency over the state before the subject of the relation between the climate of Michigan and agriculture is taken up.

Hail is an attendent upon heavy thunderstorms. It is very local in character, covering only small areas in any particular storm. On the average two hailstorms per year occur at Lansing, which may be considered a typical station for interior Michigan, but the number is less near the lake shores.

Frosts occur each fall and spring, the dates being largely influenced by the first three factors, influencing climate, i.e. latitude, altitude, and proximity of the lakes. The fourth factor should also be considered, but somewhat modified.

Latitude of course is an important factor in determining how late in the spring and early in the fall killing frosts are liable to occur. In the interior of the upper peninsula the weather remains cold until early summer and the period of warm weather is short, while in the extreme southern portion of the state it is much warmer. A table is appended giving the dates of frost and the length of the growing season at many stations in the state. From this table the following is extracted to illustrate the matter of the effect of latitude on dates of frost.

Station Latitude	Average date last killing frost in spring	Average date first killing frost in fall	Average length of growing season.
Humboldt, 46°30'	June 11	August 27	77
Adrian, 41°50'	May 7	October 25	171

Elevation has some bearing on the length of the growing season, but the matter of air drainage as affected by local influences is more important. A station on a hill side, which allows the cold air to drain off into a valley below, will escape frosts longer that a place situated at a lesser altitude.

The proximity of the lakes has a pronounced influence in preventing early frosts in the fall. At Frankfort, on Lake Michigan, the average date of the first killing frost in autumn is October 19, while at Grayling, about the same distance north, but in the interior of the state the average fall frost is more than a month earlier. Table VII and charts XI, XII and XIII show the dates of frost and the length of the growing season

Dates of killing frosts and length of growing season
UPPER PENINSULA.

Station	County	Latest date of killing frost in spring	Earliest date of killing frost in autumn	Average date last killing frost in spring.	Average date first killing frost in autumn.	Average length of the growing season in days.
Baraga,	Baraga	Jun. 27	Aug. 2	May 25	Sept. 5	103
Calumet,	Houghton	May 30	Aug. 26	May 17	Oct. 1	137
Chatham,	Alger	Jun. 28	Jul. 16	Jun. 13	Sep. 6	85
E. Harbor,	Keweenaw	Jun. 7	Sep. 13	May 23	Oct. 10	140
Escanaba,	Delta	July 9	Jul. 21	May 13	Oct. 5	145
Gd. Marais,	Alger	June 1	Sep. 12	May 17	Oct. 10	146
Houghton,	Houghton	May 27	Sep. 22	May 12	Oct. 10	151
Humboldt,	M'q't.	Jun. 28	Jul. 16	Jun. 11	Aug. 27	77
Iron Mt,	Dickinson	Jun. 15	Aug. 27	May 20	Sep. 25	128
Ironwood,	Goegebic	Jun. 13	Sep. 1	May 22	Sep. 24	125
Iron River,	Iron	Jul. 23	Jul. 23	Jun. 8	Sep. 9	93
Ishpeming,	M'q't.	Jun. 18	Jul. 26	Jun. 1	Sep. 17	107
Mackinac Island		Jun. 20	Sep. 21	May 18	Oct. 11	146
Maple Ridge,	Delta	Jun. 27	Aug. 27	Jun. 5	Sep. 11	98
Marquette,	M'q't.	Jun. 11	Aug. 22	May 13	Oct. 7	147
Menominee,	M'nee	Jun. 21	Sep. 16	May 13	Oct. 10	150
Newberry,	Luce	Jun. 20	Aug. 27	May 28	Sep. 19	105
StIgnace,	Mackinac	Jun. 28	Sep. 1	May 13	Oct. 6	146
S.S.Marie,	Chippewa	May 28	Sep. 14	May 13	Oct. 2	142
Whitefish Pt.,	do	May 28	Sep. 21	May 20	Oct. 13	146
NORTHERN COUNTIES, LOWER PENINSULA						
Alpena,	Alpena	Jun. 9	Sep. 6	May 13	Sep. 30	146
Benzonia,	Benzie	May 27	Aug. 27	May 13	Oct. 5	145
Charlevoix,	C'v'x.	Jun 10	Aug. 27	May 14	Oct. 12	151
Cheboygan,	C'b'n.	Jun. 20	Aug. 26	May 22	Sep. 24	125
East Tawas,	Iosco	Jun. 24	Aug. 22	May 20	Sep. 27	131
Frankfort,	Benzie	May 27	Sep. 29	May 10	Oct. 19	162
Grayling,	Crawford	Jun. 8	Aug. 26	May 20	Sep. 18	121
Harrison,	Clare	May 30	Aug. 27	May 14	Sep. 29	138
Harrisville,	Alcona	Jun 20	Sep. 4	May 17	Oct. 3	139
Ivan,	Otsego	Jun. 12	Aug. 26	May 23	Sep. 25	140
Ludington,	Mason	Jun. 17	Sep. 17	May 14	Oct. 8	144
Mackinaw,	Cheb'n.	Jun. 20	Aug. 26	May 20	Oct. 4	137
Mancelona,	Antrim	July 13	Aug. 26	May 28	Sep. 22	117
Manistee,	Manistee	May 28	Sep. 29	May 10	Oct. 10	153
Old Mission,	Gd. T.	Jun. 9	Sep. 29	May 13	Oct. 20	160
Omer,	Arenac	Jun. 12	Aug. 18	May 25	Sep. 21	119
Onawa,	Prisque Isle	Jun. 14	Sep. 3	May 27	Sep. 22	121
Reed City,	Osceola	Jun. 17	Aug. 23	May 22	Sep. 23	124
Roscommon,	Rosc'n	Jun. 25	Aug. 21	Jun. 14	Sep. 12	90
St. James,	C'v'x.	Jun. 9	Sep. 25	May 16	Oct. 12	149
Traverse Cy.	Gd. T.	May 31	Sep. 17	May 16	Oct. 6	143
West Branch,	Ogemaw	Jun 24	Aug. 27	May 25	Sep. 26	124

Dates of killing frosts and length of growing season
(Continued)

CENTRAL COUNTIES, LOWER PENINSULA.

Station	County	Latest date of killing frost in spring.	Earliest date of killing frost in autumn.	Average date, last killing frost in spring.	Average date, first killing frost in Autumn.	Average length of growing season, days.
Alma,	Gratiot	May 28	Sep. 2	May 12	Sep. 29	140
Arbela,	Tuscola	Jun. 9	Aug. 27	May 12	Sep. 23	134
Bay City,	Bay	May 27	Sep. 18	May 9	Oct. 12	157
Big Rapids,	Mecosta	May 29	Sep. 2	May 13	Sep. 23	133
Harbor Beach,	Huron	Jun. 4	Sep. 17	May 11	Oct. 8	150
Hart,	Oceana	May 28	Sep. 2	May 13	Oct. 8	148
Muskegon,	Muskegon	May 27	Sep. 14	May 7	Oct. 8	142
Port Austin,	Huron	Jun. 20	Sep. 10	May 16	Oct. 3	140
Saginaw,	Saginaw	May 28	Sep. 14	May 5	Oct. 7	155

Southern Counties, Lower Peninsula.

Station	County	Latest date of killing frost in spring.	Earliest date of killing frost in autumn.	Average date, last killing frost in spring.	Average date, first killing frost in Autumn.	Average length of growing season, days.
Adrian,	Lenawee	May 28	Sep. 19	May 7	Oct. 25	171
Allegan,	Allegan	Jun. 11	Sep. 5	May 13	Oct. 9	149
Ann Arbor,	Washtenaw	May 14	Sep. 22	May 4	Oct. 16	165
Battle Creek,	Calhoun	May 27	Sep. 19	May 3	Oct. 9	159
Bloomingdale,	Van Buren	May 27	Sep. 12	May 8	Oct. 10	155
Cassopolis,	Cass	May 27	Sep. 22	May 3	Oct. 13	163
Coldwater,	Branch	May 21	Sep. 18	May 3	Oct. 6	156
Detroit,	Wayne	May 31	Sep. 21	Apr. 29	Oct. 13	167
Eloise,	Wayne	May 27	Sep. 18	May 8	Oct. 9	154
Flint,	Genessee	May 27	Sep. 18	May 9	Oct. 7	151
Grape,	Monroe	May 28	Sep. 19	May 7	Oct. 13	159
Hastings,	Barry	May 28	Sep. 18	May 15	Oct. 4	142
Hillsdale,	Hillsdale	May 28	Sep. 19	May 10	Oct. 6	149
Holland,	Ottawa	May 27	Sep. 26	May 9	Oct. 9	153
Howell,	Livingston	May 28	Sep. 19	May 8	Oct. 7	152
Jackson,	Jackson	May 21	Sep. 18	May 3	Oct. 10	160
Jeddo,	St. Clair	May 28	Sep. 22	May 7	Oct. 15	161
Lansing,	Ingham	May 28	Sep. 19	May 4	Oct. 9	158
Mt Clemens,	Macomb	May 31	Sep. 19	May 13	Oct. 10	150
Owosso,	Shiawassee	Jun. 8	Sep. 14	May 13	Oct. 4	146
Plymouth,	Wayne	May 28	Sep. 2	May 7	Oct. 3	149
Pontiac,	Oakland	May 29	Sep. 11	May 11	Oct. 10	152
Port Huron,	St. Clair	Jun. 6	Sep. 22	May 6	Oct. 10	157
South Haven,	Van Buren	May 20	Sep. 21	May 3	Oct. 13	163
Ypsilanti,	Washtenaw	May 29	Sep. 14	May 10	Oct. 6	149

TABLE VII. Showing the dates of killing frosts in spring and autumn. The average dates are computed from long series of years, in some cases as many as 43. Length of growing season is number of days between killing frosts.

CHART XI,-Average date of the last killing frost in spring.

CHART XII, Average date of the first killing frost in autumn.

CHART XIII. -Average length of the growing season, in days.

Tornadoes occur infrequently in Michigan, on the average about one or two per year in the entire state. They are practically unknown in the upper peninsula. The region of most frequent occurance is in the south - central portion of the state. The Great Lakes undoubtedly decrease the number somewhat, on account of their cooling effect, therby checking the required convection. These destructive local storms occur usually in the southeastern portion of the larger disturbance, or cyclone, and as the state is in the path of greatest frequency of these cyclones, it seems reasonable to suppose that tornadoes would be more frequent in Michigan than in other states outside the path of storms, were it not for the Great Lakes.

Notable tornadoes, in recent years, were two which occurred in 1911 and 1915 respectively. The first passed through the city of Owosso, doing considerable damage and causing some loss of life. The second passed southeastward from the city limits of Charlotte, Mich., passing two miles north of Eaton Rapids, to some inland lakes southeast of Stockbridge, Mich., where it disappeared. This storm was of unusual severity and leveled everything in its path. Had it passed through any city it would have caused great loss of life and greater destruction to property.

High winds occur at intervals in connection with thunderstorms, of sufficient strength to do serious damage, but the state is still fairly well wooded and sufficiently rolling to check the wind velocity to a considerable extent. High winds are frequent on the Great Lakes, in connection with marked cyclonic formations, but their velocity is lessened as they come inland.

PART III

The Relation of the Climate of Michigan to Agriculture.

Climate and agriculture are closely related because all crops require certain amounts of heat, moisture and sunshine to make normal growths. The exact requirements of any crop for any given climatic condition are very difficult to determine and state in figures, because the relationship is complicated and plants are able to a degree to overcome unfavorable environment. Probably no exact statement has yet been made as to the most favorable temperature conditions, for example, under which a crop would thrive best, or how many heat units are necessary for any crop plant to perform its life functions to the best advantage. There have been numerous attempts to find a "thermal constant", as it has been called, for various crops, in terms of air temperature during the life phase of any crop, under the supposition that a uniform quantity of heat is necessary to produce a given increase in growth. But widely different results are found from year to year when daily air temperatures are added together over a period during which the plant is passing through a certain growth stage. Somewhat closer results are obtained by subtracting a constant amount, usually 42, from each air temperature considered, because 42°F. may be considered as zero for plant growth for ordinary farm crops. This process of adding together the remainders after subtracting 42 from each daily temperature reading, has been called the "summation method" of studying the relation between air temperature and plant growth. As stated above it does not give consistant results.

Livingston[2], Lerenbauer[3], and others have introduced van't Hoff's law, to the effect that chemical action, and hence plant growth, which is largely chemical in nature, is accelerated and doubled with each increase of 18°F in temperature, into the problem. This system seems to hold good for medium temperatures, and gives closer results than the summation process, but it fails, as does the latter also, when higher temperatures are concerned, because it takes no account of the fact that the rate of growth decreases after a certain temperature is passed.

To overcome this defect and to further perfect the system, Livingston[4] has worked out a series of values or indices of growth corresponding to each degree of temperature. These indices were determined from Lehenbauers[5] curve of growth in maize seedlings as controlled by temperature. He took the rate of growth at 40°F as unity and found values for each succeeding temperature on this basis, The highest value was 122 at 89°F, after which the indices rapidly decreased to unity again at 116°F.

When this system is applied to air temperatures it gives slightly better results for the earlier growth phases, but seems to be no improvement over earlier methods for later periods of growth. Seeley[6] has pointed out that the temperature of the plant itself is widely different than that of the air which surrounds it, especially when the sun is shining, and suggests that plant temperatures be used instead of air temperatures in studies of plant growth. He found that plant leaves were, on the average, 15°F warmer at midday, in clear weather, than the air temperature, 10°F warmer when the sun was partially obscurred in partly cloudy weather, and practically the same temperature on cloudy days. These averages were obtained from over 300 observations made during the growing season of 1915 and 1916. He proposes a formula for evaluating air temperatures in terms of the true plant temperature as follows: $T = t - 42 N + 15 C + 10 P$, where "t." is the sum of the daily maximum temperatures during a given period, "N" the number of days in the period, "C" the number of clear days and "P" the number of partly cloudy days. Applying this formula to the average temperatures at a number of stations in Michigan, using the normal number of clear, partly cloudy and cloudy days during the growing season, in each section, gives a more accurate idea of the true thermal conditions under which crops grow in this state. Chart XIV shows the results obtained in this way. It will be noted that the largest value, 7183 is about 40 per cent greater than the least value, 5048,

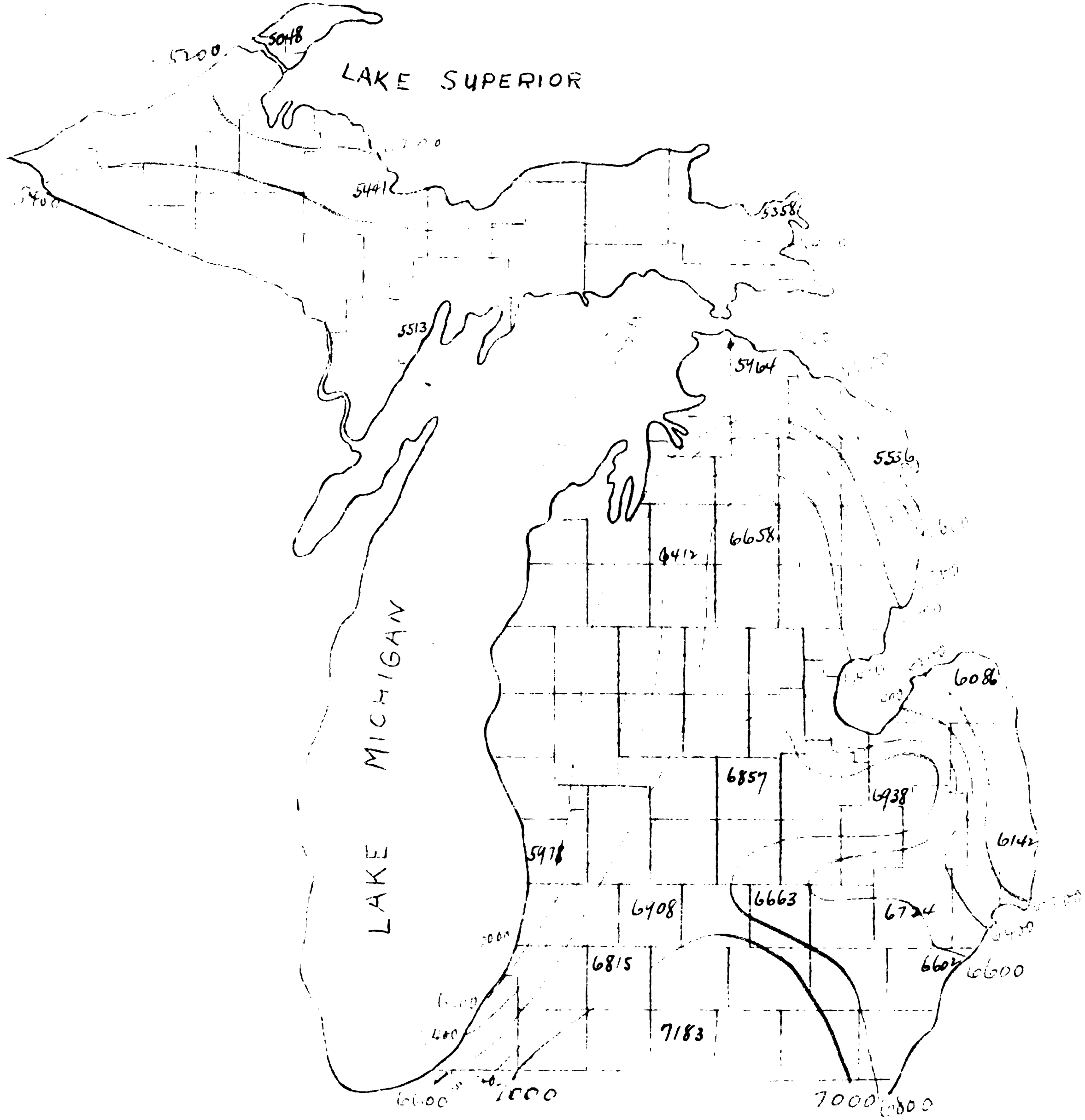


CHART XIV+-Showing the thermal values over the state found by evaluating air temperatures in terms of plant temperature, by use of formula (See Page 24) the stations having these values being, respectively, Adrian, in the extreme southern,interior, portion of the state, and Calumet, in the extreme north and on Lake Superior. It will be noted that the interior of the state has much higher termal values than sections near the lakes.

With further study and research accurate methods will probably be evolved for defining the suitibility of the temperature in any section to meet the plant requirements, but at present only the most general terms can be used. The cereal crops grown in Michigan more or less extensively are corn, wheat, oats, barley and rye. They each find temperature conditions to be a limiting factor, to a greater or less degree, in the production of a maximum crop in a rather large per cent of years.

Corn is grown to a considerable extent in Michigan, especially in the southern portion, but at least in the northern portion it is not grown as successfully as it is in the "Corn belt" states. The plant requires a rather long frostless season, with warm nights for best results,and these conditions are not found in the northern portion of the state. The crop will mature in 100 to 120 days when the weather is sufficiently warm, but 120 to 130 days are necessary to ripen it well if the weather is cool. Referring again to Charts XI, XII and XIII, showing frost dates and the length of the frostless season in various sections of Michigan it will be seen that many portions of the state are unsuitable for corn.

The winter varieties of wheat are grown exclusively in Michigan because there is usually sufficient snow to protect the crop through the winters, which are not so severe, as has been pointed out, as those in the Northwest. Some "winter killing occurs largely an account of alternate freezing and thawing when the ground is bare, but on the average the yield is satisfactory. The same statements apply to rye, which is also sown in the fall.

Oats and barley seem to find suitable temperature environment in nearly all portions of the state, and good crops are usually obtained where the soil is suitable.

Other crops which are successfully grown in Michigan on account, in a measure, of favorable temperature conditions, are hay, potatoes, beans, sugar beets, cucumbers, peas, chicory, mint and various other minor crops. It is doubtful if any other state in the union has a wider range of crops of rather large proportions than this state, largely due to the combination of marine and continental temperature conditions of this state and the local variations of other climatic elements as well, which have already been noted.

Fruit is a leading product of Michigan, largely on account of the very favorable climatic conditions produced by the Great Lakes. A narrow strip of the state extending along Lake Michigan is especially adapted to fruit and has been given the name of the "Fruit Belt" because of this fact. Among the climatic conditions found in this section that are favorable to fruit growing are, first, the continuation of cool weather into late spring which tends to retard the opening of fruit buds until danger from late frosts is past; second, unusually clear and not too hot summer weather, which produces good color and flavor in the fruit; third, prolonged cool falls, with freedom from early frosts, which tends to ripen up the wood properly, and, fourth, a moist atmosphere and freedom from extreme cold in winter which prevents winter injury. The fruit industry is still in its infancy in this favored section, but growers are beginning to realize the possibilities of the region.

The precipitation which normally falls in Michigan is sufficient for the crops which have been mentioned. But here again statements of exact relationships are as yet impossible. Briggs and Shantz[7] have worked out the actual rainfall requirements to produce a pound of dry weight in corn and Smith[8] has found that the yield of corn, potatoes and other crops is largely a matter of securing the required amount of moisture during certain short critical periods. Investigations in Italy and Russia have indicated that wheat also has a "critical period" during which the yield is determined by the amount of rain then available. But much more work must be done before the rainfall efficiency for crops can be stated for any section.

In general it is important that the precipitation for the year should be ample, and also that it should be suitably distributed through the months so that a sufficient supply will be available when the crops are growing and maturing. Reference to Chart IX shows that the most rain falls from May to September, in all parts of the state,

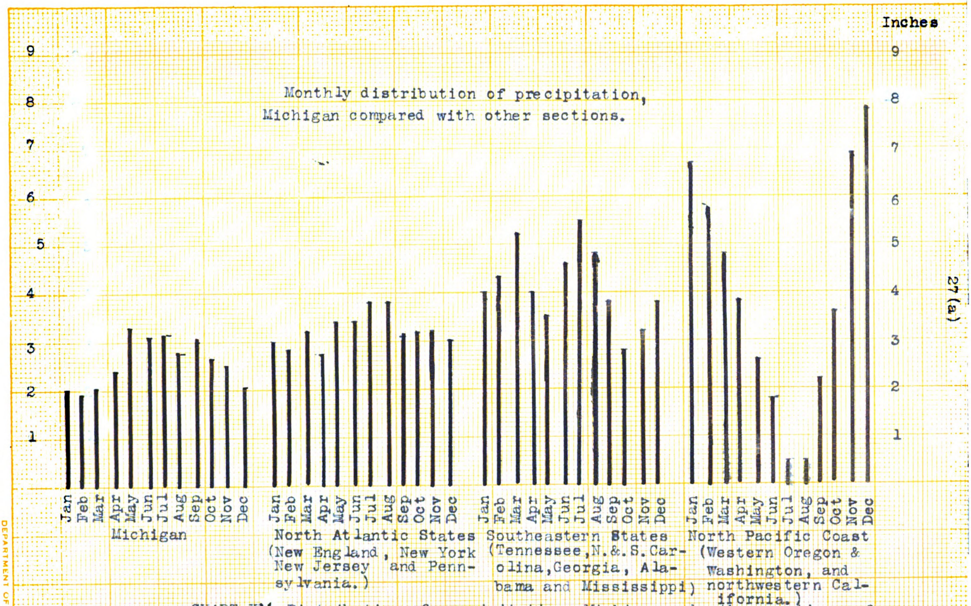
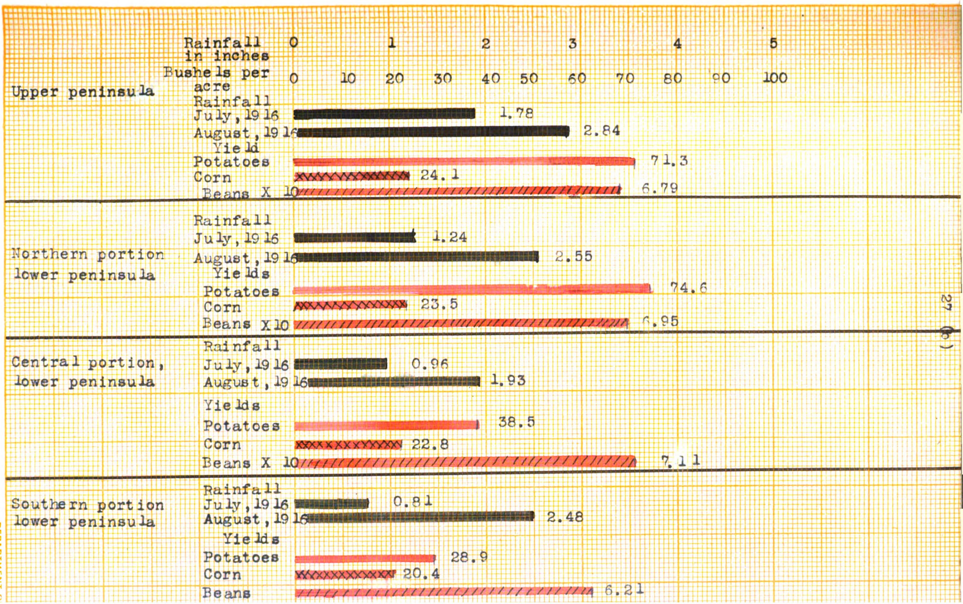


CHART XV Distribution of precipitation, Michigan and other portions of the country.


Rainfall in inches
0 1 2 3 4 5
Bushels per acre
0 10 20 30 40 50 60 70 80 90 100
Upper peninsula
Rainfall
July, 1916 1.78
August, 1916 2.84
Yield
Potatoes 71.3
Corn 24.1
Beans X 10 6.79
Northern portion lower peninsula
Rainfall
July, 1916 1.24
August, 1916 2.55
Yields
Potatoes 74.6
Corn 23.5
Beans X 10 6.95
Central portion, lower peninsula
Rainfall
July, 1916 0.96
August, 1916 1.93
Yields
Potatoes 38.5
Corn 22.8
Beans X 10 7.11
Southern portion lower peninsula
Rainfall
July, 1916 0.81
August, 1916 2.48
Yields
Potatoes 28.9
Corn 20.4
Beans 6.21

and these are the months that it is most needed. Chart XV shows the distribution in Michigan compared with that in other portions of the country, by which it will be seen that an equally satisfactory distribution does not obtain in all other sections. Occasional droughts occur in portions of the state which seriously shortens yields. One of the most serious of such droughts was that of July and August, 1916, which markedly reduced the crops of corn, potatoes, beans, sugar beets and other crops in most portions of Michigan. This affords a good opportunity for studying the relationship between precipitation shortage and crop shortage, and Chart XVI has been constructed to bring out this relationship. It will be noted that the yields of corn and potatoes are directly proportional to the July rainfall. With the exception of potatoes in the northern portion of the lower peninsula the length of the lines representing the crop yields are in the same proportion as the lines representing rainfall in July, and this discrepency may be accounted for by the fact that in the heavy potatoe producking counties in this northern section, along Lake Michigan, the rainfall was much heavier than that in the interior of the state and the eastern portion. The average yield was therefore enlarged in those sections thereby unduly enlarging the general average. In Leelanau county, for example, the fainfall for July was about two inches and the average

yield 130 bushels per acre, while in Kalkaska County nearby, the rainfall in July was little over half an inch, and the yield of potatoes but 20 bushels per acre.

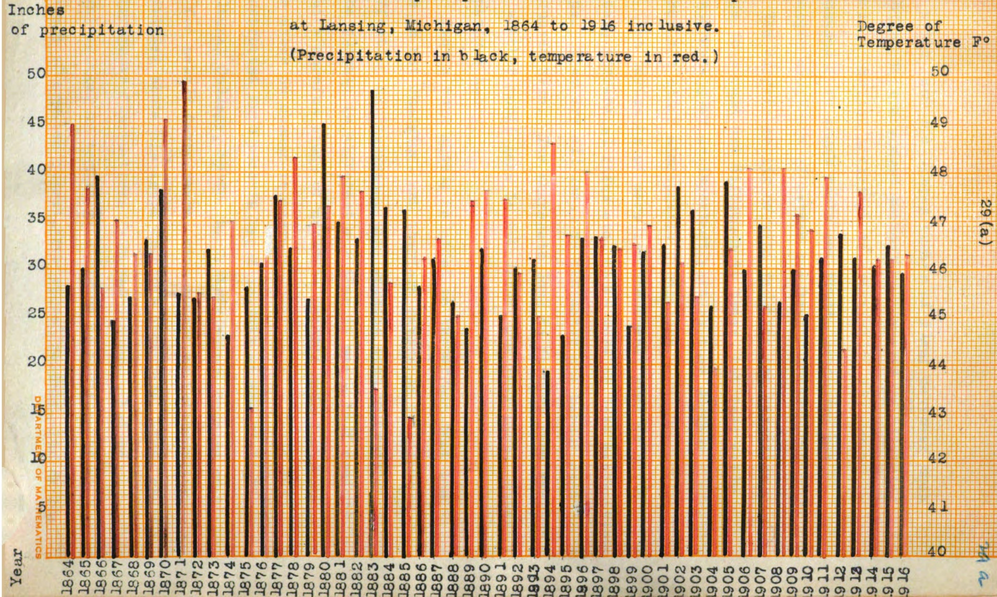
The yield of beans seems to be less closely related to the July rainfall than the other two crops mentioned, but a closer study indicates that rainfall in August in a determining factor on the yield of this crop. The average July rainfall in 1916 in ten counties which had the largest yield of beans per acre in the state last fall, was 0.96 inches and the August rainfall in the same counties 3.26 inches, while in the ten counties which yielded the least the July rainfall was about the same as in the other ten, -0.88 inches, but the August rainfall was only 2.02 inches, or more than a third less than fell in the ten counties yielding the most. The more or less even distribution of rain over the growing season, and in sufficient amounts, is therefore an important consideration where such a variety of crops are raised.

In at least two respects the unusual amount of cloudiness near the windward shores of the lakes during the winter season, mentioned in Part II, has an important bearing on agriculture. One of these is the beneficial and protective influence on fruit trees over winter, as stated. Were it not for this cloudy, moist atmosphere injury would more often result, as it does in other sections, from drying out of the wood. Second, cloudiness prevents thawing of wheat and rye fields on winter days, which is injurious when followed by freezing at night.

CHART XVII

Total annual precipitation and mean annual temperature at Lansing, Michigan, 1864 to 1916 inclusive.

(Precipitation in black, temperature in red.)



On the other hand the larger number of clear daysover much of Michigan in the summer season, as compared with adjoining states is a decided advantage to practically all crops, but especially to sugar beets and fruit, producing not only larger crops but of better quality.

The direct bearing of wind velocity and direction on crops is slight and difficult to trace, but indirectly these elements play an important part as they largely influence the other atmospheric conditions.

The occurance of peculiar phenomena, such as hail, tornadoes, torrential rains etc. cause more or less destruction to crops. They are all local in character and hardly need be discussed here. The aggregate loss to farmers from these severe weather conditions is not large, but individual losses are sometimes heavy.

Just a word should be added to the effect that the climate is not changing, and therfore favorable or unfavorably affecting agriculture. Many persons seem to believe that the climate is different now than it was a half century ago, but a careful study of accurate records made for long periods shows no change in average conditions. Chart XVII was constructed from records begun in 1863 at the Michigan Agricultural College, by Dr. R. C. Kedzie, and carried on by him for nearly forty years, with almost no interruption, and continued since his death by other observers. This chart shows irregular fluctuations from year to year, but no permanent change, or tendency to change in any direction. The average of any ten consecutive years' records, during the period, either of rainfall or temperature , will be found to be about equal to that of any other period of equal length.

SUMMARY.

The purpose of this paper is to describe the climate of Michigan, and explain its peculiarities, and then to correlate the climate as described with the agriculture of the state.

The influences which control climate are four, namely latitude, altitude, environmental surroundings and the location relative to the normal storm paths.

The temperature decreases in this and other sections about one degree per one-hundred miles in distance away from the equator. A rise of about 300 feet in elevation causes a drop in temperature of about 1°F. The presence of the Great Lakes causes marked differences in the climate of Michigan as compared with other sections. The windward side of the lakes have a much more equable temperature, more snowfall and cloudiness in winter and more sunshine in summer, than interior regions. The fact that Michigan is in the direct path of cyclones and anti-cyclones results in frequent weather changes, more precipitation which is well distributed, and invigorating weather conditions generally.

On the whole the Climate of Michigan is not extreme in temperature, either in summer or winter, the rainfall is sufficient for most crops, the most of the year's supply falling during the growing season; the cloudiness is greater in winter and less in summer than in regions remote from the Great Lakes; the humidity is rather high throughout the year, especially on the lake shores; the prevailing winds are westerly, often high on the lakes but decrease as they pass inland. Severe local phenomena such as hail, tornadoes, torrential rains etc. occur infrequently.

The usual cereal crops grown in the central valleys are raised in Michigan. Corn can be grown about as successfully in southern Michigan as in the "Corn Belt", but the seasons are often too short in the northern portion of the state to mature the crop. Wheat, oats, rye, barley, potatoes, beans, sugar beets, are all important crops, while many minor crops are also produced. There are localities where each seems to find particularly favorable climatic conditions in the state, which has an unusually wide variation in climate. The "Fruit Belt" along the Lake Michigan coast is pecularily adapted, as to climate for growing fruit on account or its cool springs, moderate summers with much sunshine, late falls and mild winters with much snow and cloudiness.

The climate is not changing as shown by a study of over fifty years of records made at the Michigan Agricultural College.

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Location of Observing and Forecast Distributing Stations.

⊙ Meteorological observations Regular Weather Bureau stations

○ Meteorological observations Sub stations

△ Display or distribution of forecasts

Annual Precipitation. 1916