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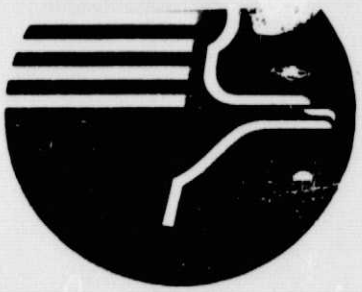
LACIE-00433 (REV. A)
JSC-11658

LARGE AREA CROP INVENTORY EXPERIMENT (LACIE)

NASA NOAA USDA

YIELD-WEATHER REGRESSION MODELS FOR THE CANADIAN PRAIRIES



National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER
Houston, Texas

JUNE, 1977

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NOAA PERSONNEL

CENTER FOR CLIMATIC AND ENVIRONMENTAL ASSESSMENT

COLUMBIA, MISSOURI

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JUNE 1977

Jerry D. Hill
for
Authorized by
Norton D. Strommen
Acting Director, CCEA
July 19, 1977

PREFACE

The Canadian yield models described here are improved versions of the models released by CCEA in 1976. A new historical data base with a denser network of weather reporting stations became available plus an additional year of observations was added. The data were reanalyzed and the significant variables as well as the coefficients have changed for several regional models.

Yield-Weather Regression Models for the Canadian Prairies

Sharon K. LeDuc

The Canadian prairie wheat region has in recent years produced about 5.7 percent of the world's wheat. Most of this wheat is exported and accounts for about 18.4 percent of the world's wheat exports. The major wheat growing area is shaded in Figure 1. There is generally a moisture shortage in this region due to the Rocky Mountains which restrict moisture from the Pacific Ocean. Most of the variability in wheat production is due to weather fluctuations. Climatic differences within the region account for a large portion of the variability in yields for different parts of the region. Separate regression models were developed for each of the areas indicated in Figure 1.

Yield Data

The available production and seeded acreage data determined what areas would be used for specifying the models. A consistent sample of yields for as many years as possible was required. Annual yields from 1933-1974 were available although the geographical areas for reporting acreage and production changed during the time period. For some model areas, this required reaggregation of available acreage and production data. Dividing the annual total production by the annual total seeded acreage in each area provided an annual yield for each model area for each year.

For Saskatchewan no reaggregation of production and planted acreage for the model areas was necessary. Model areas for Alberta differ prior

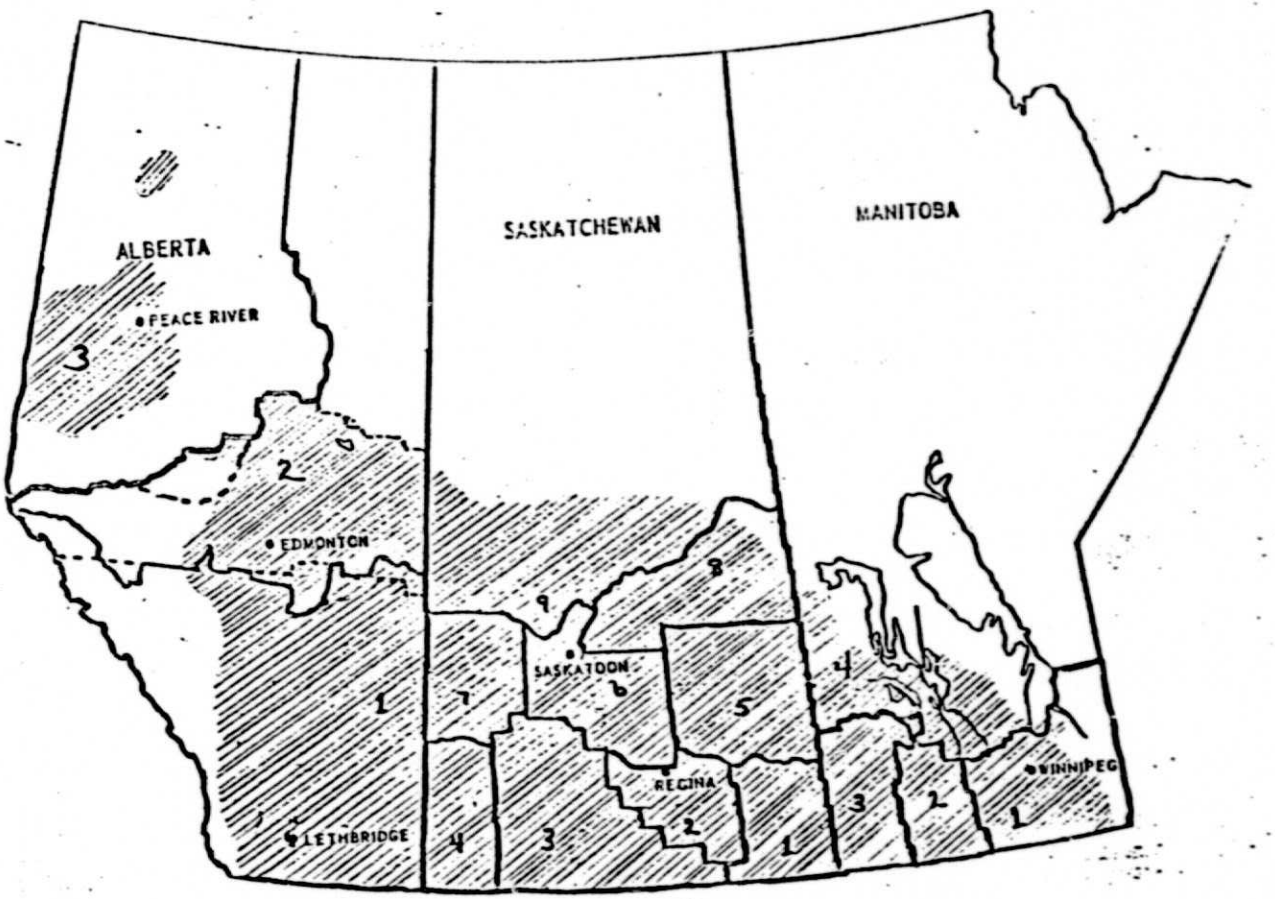

Figure 1. Outline map of the Prairie Provinces showing model areas and wheat area shaded.

to 1956 (dotted lines, Figure 1). Manitoba model regions are consistent, 1936-1974. There were slight deviations for 1933-1935.

Weather Data

Monthly weather summaries consisting of mean maximum temperature, mean minimum temperature, mean temperature and total precipitation were available for stations in the Prairie Provinces. All available stations were accepted if they were in the wheat producing region. Values for the monthly weather variables were averaged over all stations in the same model area. The number of stations varied for different areas. These are given in Table 1.

Table 1. Reaggregation of Reported Acres and Production into Model Areas

Province and Reporting Area	Model Area	Reporting Areas
Alberta-	1	1-9
Census Divisions	2	10-14
	3	15
Saskatchewan-	1	1a, 1b
Crop Districts	2	2a, 2b
	3	3as, 3an, 3bs, 3bn
	4	4a, 4b
	5	5a, 5b
	6	6a, 6b
	7	7a, 7b
	8	8a, 8b
	9	9a, 9b
Manitoba-	1	3-6
Crop Districts	2	2, 8, 9
	3	1, 7, 10
	4	11-14

The monthly average temperature for a model area was sometimes converted to a measure of potential evapotranspiration (P.E.T.) using a method developed by Thornthwaite (1948), briefly explained in Appendix A. The P.E.T was subtracted from the precipitation yielding a measure of the moisture available for that month.

The soil moisture available at planting is one of the variables affecting yields especially when fertilizer is applied (Read and Warder, 1974). To measure this the monthly precipitation values were accumulated for a period of 20 months prior to the normal month of planting which is May for most of Canada. The period of 20 months was used because of the extensive practice of summerfallowing. There have been minor changes in the percent of acres in summerfallow during the period 1916-1968 (Figure 2). Any downward shift of this practice would result in decreasing the yield potential. The effect of summerfallow on yield can be seen in Table 2.

Table 2. Summerfallow Versus Stubble Distribution and Yield for Wheat

		Distribution (%)		Yield (Bu/A)	
Province	Year	Stubble	Summerfallow	Stubble	Summerfallow
Saskatchewan	1960	25	75	15.2	22.6
	1961	27	73	4.3	9.7
	1963	17	83	20.6	29.0
	1964	20	80	13.1	19.4
	1965	21	79	17.8	22.6
	1966	25	75	22.1	29.6
	1967	28	72	12.9	18.9
	1968	24	76	14.1	21.3
	1968-72 avg	15	85	16.7	25.5
	1972	18	82	16.8	24.9
	1973	16	84	18.6	25.5
	1974	20	80	16.0	22.5
Alberta	1968-72 avg	23	77	20.4	28.4
	1972	23	77	23.0	28.7
	1973	18	82	21.6	28.6
	1974	22	78	21.0	25.4

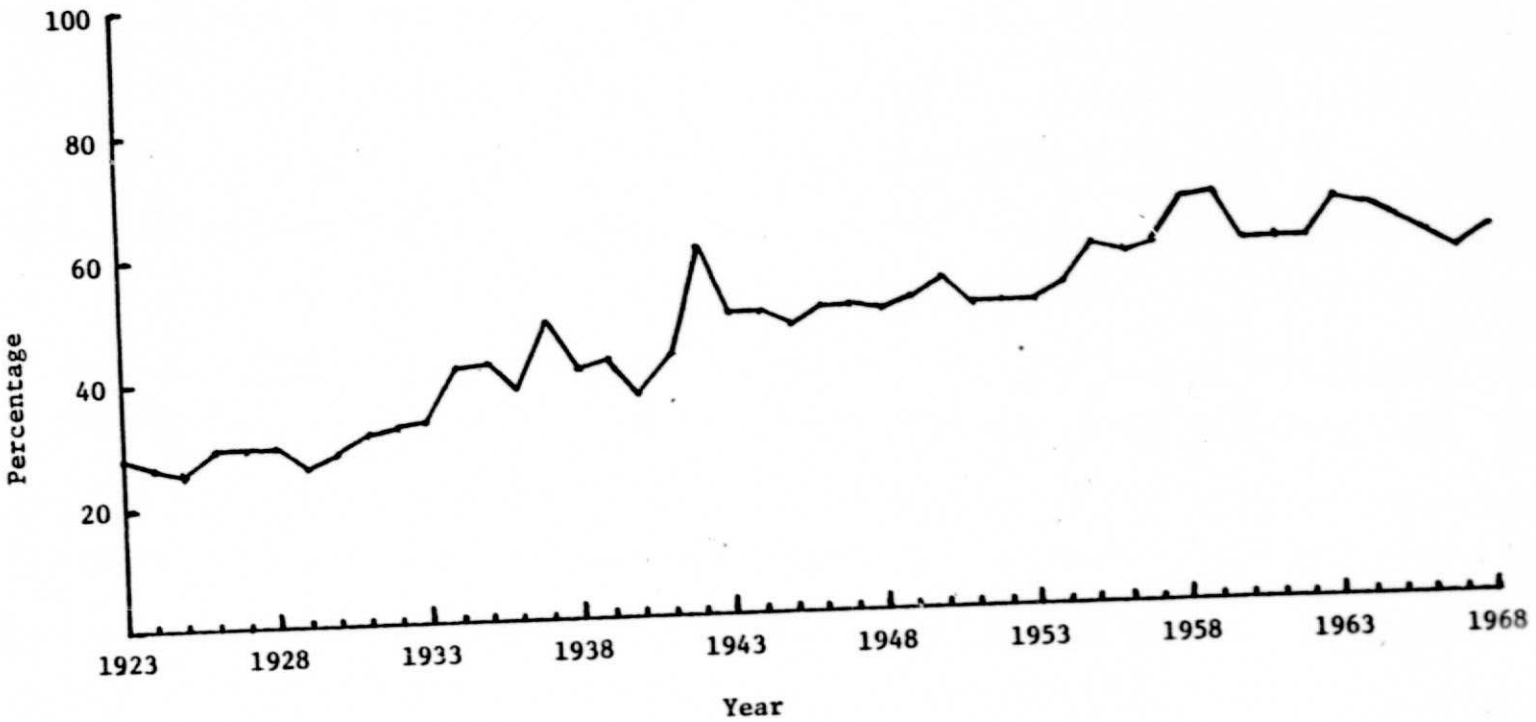

Figure 2. Percentage of Planted Acres in Saskatchewan Which Were Summerfallowed (1923-1968).

Although more humid than either Saskatchewan or Alberta, Manitoba summerfallow is also used quite extensively, largely as a weed control measure (Table 3). However, yield on stubble and summerfallow are not reported separately and wheat planted on fallow is also not reported separately.

Table 3. Manitoba Wheat Acres and Summerfallow

Year	Summerfallow (Acres)	Wheat Planted
1971	2,655,000	2,519,000
1972	2,900,000	2,600,000
1973	2,400,000	3,100,000
1974	2,500,000	3,000,000
1975	2,600,000	3,100,000
1976	2,600,000	3,800,000

For some of the model areas farther north the mean minimum and mean maximum monthly temperatures are important as indicators of the length of the growing season.

All weather variables are in terms of deviations from normal (DFN); i.e., the sample average is subtracted. The square of this deviation is sometimes used (SDFN).

Regression Model

The general form of the regression model for yield y for a particular model area is

$$y_i = \alpha + \beta T_i + \sum_{j=1}^{k} \gamma_j W_{ij} + \varepsilon_i,$$

where:

y_i is the yield for year i,

α is the intercept estimated in the regression,

β, γ_j, j=1,2,...k are parameters estimated in the regression,

T_i is a time variable for the ith year found by subtracting 1932 from the year,

W_{ij} is one of the weather variables (the jth) described in the previous section for the ith year,

ε_i is the deviation of the yield from the regression for the ith year. (Errors are assumed to be independent and normally distributed with mean zero and unit standard deviation,)

Discussion of Models

The deviation from normal of summerfallow was a variable which was significant in all models for all model ares in Alberta and Saskatchewan except area 2 in Alberta. The sign of the coefficient was positive for all these areas except for area 3 in Alberta. This area also had the third highest normal for summerfallow precipitation. Only areas 1 and 4 in Manitoba were higher.

In estimating the coefficients in the regression equations the years 1933-1953 and 1955-1975 were used with a few exceptions. Area 1 in Alberta and area 4 in Saskatchewan included 1954 and area 1 in Manitoba omitted 1963. The years were omitted due to severe rust lossess (Williams, 1972). Although losses due to rust are affected by the weather the wheat must be vulnerable to the rust present.

The September minimum temperature DFN appears in the models for Alberta and for model areas 6 and 9 in Saskatchewan. Higher minimum

in September indicate higher yields except for model area 3 in Alberta. There they are associated with lower yields; however, higher maximum temperatures in May indicate higher yields.

The minimum temperature in April which is higher than normal indicated higher yields for model areas 1, 2, 5, and 9 in Saskatchewan, and 2 and 3 in Manitoba. The opposite effect was noticed for model area 7 in Saskatchewan. However, for later estimates, decreased yields were indicated.

Higher precipitation or precipitation minus potential evapotranspiration in May increases yield in model areas 1, 3, 4, and 6 in Saskatchewan and area 3 in Alberta.

For the months of June through August, the deviation from normal of the precipitation minus the potential evapotranspiration and/or the squared deviation were used. The estimated coefficients of the squared deviations were negative indicating extreme deviations in either direction decrease yields. With only four exceptions the estimated coefficients for the deviations were positive indicating more moisture improved yields. The fitted models for areas 2 and 3 in Alberta and for areas 8 and 9 in Saskatchewan indicated yields were decreased when August precipitation minus potential evapotranspiration was above normal. The model for area 7 in Saskatchewan does not contain meteorological variables for months after July.

High September minimum temperatures are associated with high yields in areas 1 and 2 in Alberta and areas 6 and 9 in Saskatchewan. Alberta 3 shows the opposite effect in the linear terms.

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Read, D. W. L. and F. G. Warder, 1974: Influence of Soil and Climatic Factors on Fertilizer Response of Wheat Grown on Stubble Land in Southwestern Saskatchewan. Agronomy Journal, 66:245-248.

Thornthwaite, C.W., 1948: An Approach Toward a Rational Classification of Climate. Geographical Review, 38:55-94.

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Appendix A

Thornthwaite

1. Unadjusted Potential Transpiration, P.E.T. $P.E.T. = 1.6\left(\frac{(10.0)(t)}{I}\right)^{a}$

in centimeters of water per 30 day month, with each day having 12 hours of sunlight. If $i_k = (t_k/5.0)^{1.514}$, where

t_k = monthly normal temperature, C^o,

t_1 = monthly normal temperature, January,

t_2 = monthly normal temperature, February,

t_3 = monthly normal temperature, March,

t_4 = monthly normal temperature, April,

t_5 = monthly normal temperature, May,

t_6 = monthly normal temperature, June,

t_7 = monthly normal temperature, July,

t_8 = monthly normal temperature, August,

t_9 = monthly normal temperature, September,

t_{10} = monthly normal temperature, October,

t_{11} = monthly normal temperature, November,

t_{12} = monthly normal temperature, December,

$$I = \sum_{k=1}^{12} i_k$$

$$a = (675)(10^{-9})I^3 - (771)(10^{-7})I^2 + (1792)(10^{-5})I + .49239.$$

2. Adjusted P.E.T. = (c)(unadjusted P.E.T.), where c is a daylength factor = c = (h/12.0), where h = number of hours (to nearest hundredth) between sunrise and sunset for mid month.

ALBERTA 1

Region

Alberta Crop Region 1

P.E.T. A = .883
P.E.T. I = 23.701

May Daylength = 1.2880
June Daylength = 1.3600
July Daylength = 1.3170
August Daylength = 1.1867

Latitude = 51°N

Variable	Deviation	Normal	Trend	April	May	June	July	August	September
Constant		1.00	7.63051	8.92973	7.99348	8.04407	9.48737	9.56162	9.58741
Linear Trend		45.00	0.24400	0.22039	0.21966	0.20901	0.16771	0.16462	0.17016
Fallow Prec 20 Mo - Apr (mm)	DFN	693.26		0.01503	0.01539	0.01157	0.01596	0.01547	0.01564
Fallow Prec 20 Mo - Apr (mm)	SDFN	693.26		-0.00003	-0.00002	-0.00000	-0.00005	-0.00005	-0.00006
Apr Min Temp (°C)	DFN	-2.96		-0.12587	-0.11648	-0.11155	-0.09010	-0.10215	-0.10795
May Prec - P.E.T. (mm)	DFN	-24.29			0.00142	0.00147	0.00124	0.00132	0.00127
Jun Prec - P.E.T. (mm)	DFN	-18.21				0.03727	0.03157	0.03041	0.03038
Jul Prec - P.E.T. (mm)	DFN	-69.61					0.05243	0.05429	0.05284
Aug Prec - P.E.T. (mm)	DFN	-54.47						0.01299	0.01254
Sep Min Temp (°C)	DFN	3.18							0.49055
R Squared			0.53091	0.61933	0.67283	0.77811	0.86027	0.86890	0.89483
Standard Error (Q/Ha)			2.91487	2.72750	2.56250	2.13945	1.72184	1.69216	1.53841
Standard Variance (Q/Ha)^2			8.49647	7.43925	6.56641	4.57726	2.96473	2.86342	2.36670

Standard Deviation of Yields = 4.2[illegible]91 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1975
Meteorological Normals Based on 1933-1975

June 1977

ALBERTA 2

Region

Alberta Crop Region 2

P.E.T. A = .852
P.E.T. I = 21.714

June Daylength = 1.4254
July Daylength = 1.3725
August Daylength = 1.2170

Latitude = 55°N

Variable	Deviation	Normal	Trend	April	June	July	August	September
Constant		1.00	10.66858	11.91175	12.05277	12.49929	12.34314	12.52377
Linear Trend		45.00	0.18643	0.16405	0.15150	0.13449	0.13996	0.13333
Apr Min Temp (°C)	DFN	-3.61		-0.15759	-0.10372	-0.11497	-0.11188	-0.11654
Jun Prec - P.E.T. (mm)	DFN	-25.69			0.04675	0.04799	0.04855	0.05569
Jul Prec - P.E.T. (mm)	DFN	-38.91				0.02496	0.02328	0.02303
Aug Prec - P.E.T. (mm)	DFN	-32.39					-0.00618	-0.01291
Sep Min Temp (°C)	DFN	2.92						0.60583
R Squared			0.40606	0.49271	0.66362	0.68824	0.69052	0.73880
Standard Error (Q/Ha)			2.90115	2.71533	2.24002	2.18543	2.20744	2.05675
Standard Variance $(Q/Ha)^2$			8.41665	7.37299	5.01768	4.77609	4.87279	4.23022

Standard Deviation of Yields = 3.71822 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1953, 1955-1975
Meteorological Normals Based on 1933-1975

June 1977

ALBERTA 3

Region

Alberta Crop Region 3

P.E.T. A = .833
P.E.T. I = 20.508

June Daylength = 1.3906
July Daylength = 1.3431
August Daylength = 1.2011

Latitude = 53°N

Variable	Deviation	Normal	Trend	April	May	June	July	August	September
Constant		1.00	12.48785	12.12474	12.19717	14.11789	14.74074	14.41440	14.18387
Linear Trend		45.00	0.05799	0.07349	0.07117	0.01574	0.02286	0.03260	0.03718
Fallow Prec 20 Mo - Apr	DFN	696.33		-0.00530	-0.00488	-0.00354	-0.00401	-0.00354	-0.00409
May Prec (mm)	DFN	39.29			0.03658	0.02523	0.03329	0.04078	0.03037
Jun Prec - P.E.T. (mm)	DFN	-33.66				0.07033	0.06541	0.06623	0.05963
Jun Prec - P.E.T. (mm)	SDFN	-33.66				-0.00050	-0.00058	-0.00054	-0.00046
Jul Prec - P.E.T. (mm)	DFN	-40.98					0.00888	0.01225	0.00979
Jul Prec - P.E.T. (mm)	SDFN	-40.98					-0.00068	-0.00062	-0.00059
Aug Prec - P.E.T. (mm)	DFN	-35.41						-0.01948	-0.01490
Sep Min Temp (°C)	DFN	2.85							-0.47430
R Squared			0.04625	0.06989	0.10911	0.50687	0.57883	0.60401	0.63593
Standard Error (Q/Ha)			3.38814	3.38852	3.35965	2.56805	2.44211	2.40358	2.34040
Standard Variance $(Q/Ha)^2$			11.47950	11.48208	11.28726	6.59488	5.96391	5.77722	5.47749

Standard Deviation of Yields = 3.42675 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1953, 1955-1975
Meteorological Normals Based on 1933-1975

June 1977

SASKATCHEWAN 1

Region

Saskatchewan Crop Region 1

P.E.T. A = .938
P.E.T. I = 27.280

May Daylength = 1.2773
June Daylength = 1.3460
July Daylength = 1.3049
August Daylength = 1.1800

Latitude = 50°N

Variable	Deviation	Normal	Trend	April	May	June	July	August
Constant		1.00	6.69559	7.09052	7.57885	7.19581	7.32246	7.41224
Linear Trend, 1930-1975		45.00	0.23798	0.22051	0.20107	0.24875	0.23945	0.23420
Fallow Prec 20 Mo - Apr	DFN	628.09		0.01230	0.01267	0.00915	0.00861	0.00869
Apr Min Temp (°C)	DFN	-3.06		0.59247	0.62829	0.41468	0.32865	0.29575
May Prec - P.E.T. (mm)	DFN	-24.78			0.03559	0.02762	0.02025	0.01972
Jun Prec - P.E.T. (mm)	DFN	-25.62				0.05170	0.05042	0.04742
Jun Prec - P.E.T. (mm)	SDFN	-25.62				-0.00034	-0.00028	-0.00026
Jul Prec - P.E.T. (mm)	DFN	-71.72					0.02485	0.02593
Aug Prec - P.E.T. (mm)	DFN	-51.31						0.00990
R Squared			0.39995	0.52296	0.56845	0.73518	0.76205	0.76868
Standard Error (Q/Ha)			3.75060	3.43103	3.30714	2.66364	2.56175	2.56380
Standard Variance (Q/Ha)^2			14.06703	11.7719[illegible]	10.93720	7.09500	6.56258	6.57307

Standard Deviation of Yields = 4.78240 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1953, 1955-1975
Meteorological Normals Based on 1933-1975

June 1977

SASKATCHEWAN 2

Region

Saskatchewan Crop Region 2

P.E.T. A = .958
P.E.T. I = 28.656

June Daylength = 1.3460
July Daylength = 1.3049
August Daylength = 1.1800

Latitude = 50°N

Variable	Deviation	Normal	Trend	April	May	June	July	August
Constant		1.00	6.10022	6.36344	8.01548	8.03827	8.08373	7.94045
Linear Trend		45.00	0.26922	0.25832	0.23448	0.26339	0.26003	0.27881
Fallow Prec 20 Mo - Apr	DFN	522.07		0.01484	0.01604	0.01343	0.01304	0.01246
Apr Min Temp (°C)	DFN	-2.84		0.82987	0.74100	0.57414	0.46573	0.37563
May Max Temp (°C)	DFN	18.22			-0.19374	-0.16559	-0.16002	-0.15780
Jun Prec - P.E.T. (mm)	DFN	-32.89				0.04950	0.04883	0.03915
Jun Prec - P.E.T. (mm)	SDFN	-32.89				-0.00060	-0.00059	-0.00040
Jul Prec - P.E.T. (mm)	DFN	-81.41					0.01804	0.01730
Aug Prec - P.E.T. (mm)	DFN	-62.29						0.02462
Aug Prec - P.E.T. (mm)	SDFN	-62.29						-0.00044
R Squared			0.46041	0.60269	0.67034	0.85396	0.86264	0.87848
Standard Error (Q/Ha)			3.75005	3.30146	3.04765	2.08562	2.05224	1.98965
Standard Variance $(Q/Ha)^2$			14.06290	10.89963	9.28816	4.34981	4.21167	3.95870

Standard Deviation of Yields = 5.04246 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1953, 1955-1975
Meteorological Normals Based on 1933-1975

June 1977

SASKATCHEWAN 3

Region

Saskatchewan Crop Region 3

P.E.T. A = .963
P.E.T. I = 28.956

June Daylength = 1.3460
July Daylength = 1.3049
August Daylength = 1.1800

Latitude = 50°N

Variable	Deviation	Normal	Trend	April	May	June	July	August
Constant		1.00	4.62015	5.55145	5.79678	4.94660	5.86928	6.01731
Linear Trend, 1930-1975		45.00	0.24057	0.20314	0.19221	0.22730	0.20507	0.21244
Fallow Prec 20 Mo - Apr	DFN	502.65		0.01989	0.01978	0.01565	0.01710	0.01825
May Prec - P.E.T. (mm)	DFN	-35.36			0.03517	0.02922	0.02326	0.02181
Jun Prec - P.E.T. (mm)	DFN	-37.88				0.06393	0.06114	0.05837
Jul Prec - P.E.T. (mm)	DFN	-87.65					0.07192	0.07171
Jul Prec - P.E.T. (mm)	SDFN	-87.65					-0.00045	-0.00045
Aug Prec - P.E.T. (mm)	DFN	-70.42						0.00866
Aug Prec - P.E.T. (mm)	SDFN	-70.42						-0.00031
R Squared			0.38306	0.49697	0.53405	0.75652	0.87669	0.88213
Standard Error (Q/Ha)			3.92822	3.59227	3.50253	2.56588	1.87743	1.89034
Standard Variance $(Q/Ha)^2$			15.43095	12.90438	12.26771	6.58376	3.52474	3.57340

Standard Deviation of Yields = 4.93985 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1953, 1955-1975
Meteorological Normals Based on 1933-1975

June 1977

SASKATCHEWAN 4

Region

Saskatchewan Crop Region 4

P.E.T. A = .946
P.E.T. I = 27.829

May Daylength = 1.2733
June Daylength = 1.3460
July Daylength = 1.3049
August Daylength = 1.1800

Latitude = 50°N

Variable	Deviation	Normal	Trend	April	May	June	July	August
Constant		1.00	3.24352	4.72051	5.04874	4.62740	4.95287	5.20534
Linear Trend, 1930-1975		45.00	0.25593	0.19606	0.18337	0.20018	0.18889	0.19411
Fallow Prec 20 Mo - Apr	DFN	503.42		0.02695	0.02591	0.02118	0.01957	0.02058
May Prec - P.E.T. (mm)	DFN	-39.31			0.03497	0.03286	0.02615	0.01965
Jun Prec - P.E.T. (mm)	DFN	-39.05				0.05329	0.05522	0.05232
Jul Prec - P.E.T. (mm)	DFN	-83.95					0.03703	0.03919
Aug Prec - P.E.T. (mm)	DFN	-74.38						0.02138
Aug Prec - P.E.T. (mm)	SDFN	-74.38						-0.00041
R Squared			0.40636	0.63341	0.66593	0.78378	0.82638	0.83931
Standard Error (Q/Ha)			3.98005	3.16747	3.06325	2.49751	2.26883	2.24603
Standard Variance $(Q/Ha)^2$			15.84078	10.03290	9.38352	6.23756	5.14761	5.04467

Standard Deviation of Yields = 5.10228 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1953, 1955-1975
Meteorological Normals Based on 1933-1975

June 1977

SASKATCHEWAN 5

Region

Saskatchewan Crop Region 5

P.E.T. A = .908
P.E.T. I = 25.324

June Daylength = 1.3600
July Daylength = 1.3170
August Daylength = 1.1867

Latitude = 51°N

Variable	Deviation	Normal	Trend	April	June	July	August
Constant		1.00	11.53143	11.88517	12.51682	12.68852	12.67529
Linear Trend, 1930-1975		45.00	0.14775	0.13429	0.17194	0.16190	0.17009
Fallow Prec 20 Mo - Apr	DFN	616.47		0.00907	0.00541	0.00621	0.00694
Apr Min Temp (°C)	DFN	-3.90		0.38674	0.17868	0.14133	0.13274
Jun Prec - P.E.T. (mm)	DFN	-32.70			0.04887	0.04559	0.04425
Jun Prec - P.E.T. (mm)	SDFN	-32.70			-0.00101	-0.00096	-0.00084
Jul Prec - P.E.T. (mm)	DFN	-70.08				0.02143	0.01919
Aug Prec - P.E.T. (mm)	DFN	-54.25					-0.00038
R Squared			0.24303	0.31783	0.68486	0.70851	0.71750
Standard Error (Q/Ha)			3.35504	3.26770	2.28185	2.22571	2.22309
Standard Variance $(Q/Ha)^2$			11.25628	10.67787	5.20685	4.95378	4.94212

Standard Deviation of Yields = 3.80887 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1953, 1955-1975
Meteorological Normals Based on 1933-1975

June 1977

SASKATCHEWAN 6

Region

Saskatchewan Crop Region 6

P.E.T. A = .946
P.E.T. I = 27.832

June Daylength = 1.3600
July Daylength = 1.3170
August Daylength = 1.1867

Latitude = 51°N

Variable	Deviation	Normal	Trend	April	May	June	July	August	September
Constant		1.00	5.81825	6.31172	6.67436	6.33661	7.45884	7.52192	7.37014
Linear Trend, 1930-1975		45.00	0.24356	0.22403	0.21960	0.23913	0.20012	0.19844	0.20091
Fallow Prec 20 Mo - Apr	DFN	520.40		0.01599	0.01639	0.01625	0.01519	0.01551	0.01457
May Max Temp (°C)	SDFN	18.32			-0.05535	-0.07593	-0.10138	-0.10255	-0.08425
May Prec (mm)	DFN	35.84			0.00696	0.04033	0.03517	0.03337	0.04026
Jun Prec - P.E.T. (mm)	DFN	-40.64				0.07002	0.06844	0.06751	0.06999
Jul Prec - P.E.T. (mm)	DFN	-80.87					0.07071	0.07110	0.06705
Aug Prec - P.E.T. (mm)	DFN	-68.23						0.00603	0.00036
Sep Min Temp (°C)	DFN	4.24							0.35823
R Squared			0.40371	0.47241	0.47799	0.78722	0.91892	0.91987	0.93084
Standard Error (Q/Ha)			3.80870	3.62822	3.70522	2.39821	1.50140	1.51434	1.42811
Standard Variance $(Q/Ha)^2$			14.50621	13.16397	13.72865	5.75143	2.25419	2.29322	2.03950

Standard Deviation of Yields = 4.87175 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1953, 1955-1975
Meteorological Normals Based on 1933-1975

June 1977

SASKATCHEWAN 7

Region

Saskatchewan Crop Region 7

P.E.T. A = .930
P.E.T. I = 26.803

June Daylength = 1.3748
July Daylength = 1.3296

Latitude = 52°N

Variable	Deviation	Normal	Trend	April	June	July
Constant		1.00	4.97618	7.08482	6.99446	8.64567
Linear Trend, 1930-1975		45.00	0.29858	0.24248	0.24604	0.19363
Fallow Prec 20 Mo - Apr	DFN	481.98		0.03520	0.02605	0.02364
Apr Min Temp (°C)	SDFN	-3.30		-0.19077	-0.08870	-0.09337
Jun Prec - P.E.T. (mm)	DFN	-47.16			0.07390	0.07119
Jun Prec - P.E.T. (mm)	SDFN	-47.16			-0.00039	-0.00028
Jul Prec - P.E.T. (mm)	DFN	-78.50				0.07196
Jul Prec - P.E.T. (mm)	SDFN	-78.50				-0.00065
R Squared			0.46659	0.65172	0.79399	0.89283
Standard Error (Q/Ha)			4.10758	3.40534	2.69076	1.99700
Standard Variance $(Q/Ha)^2$			16.87219	11.59636	7.24021	3.98802

Standard Deviation of Yields = 5.55513 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1953, 1955-1975
Meteorological Normals Based on 1933-1975

June 1977

SASKATCHEWAN 8

Region

Saskatchewan Crop Region 8

P.E.T. A = .905
P.E.T. I = 25.122

June Daylength = 1.3906
July Daylength = 1.3431
August Daylength = 1.2011

Latitude = 53°N

Variable	Deviation	Normal	Trend	April	June	July	August
Constant		1.00	11.69740	11.55118	12.76797	14.29788	14.22364
Linear Trend, 1930-1975		45.00	0.15582	0.16178	0.15086	0.09881	0.10293
Fallow Prec 20 Mo - Apr	DFN	619.28		-0.00182	0.00332	0.00492	0.00472
Jun Prec - P.E.T. (mm)	DFN	-37.68			0.05924	0.05388	0.05449
Jun Prec - P.E.T. (mm)	SDFN	-37.68			-0.00053	-0.00044	-0.00045
Jul Prec - P.E.T. (mm)	DFN	-68.08				0.04490	0.04410
Jul Prec - P.E.T. (mm)	SDFN	-68.08				-0.00036	-0.00036
Aug Prec - P.E.T. (mm)	DFN	-58.39					-0.00399
R Squared			0.29021	0.29187	0.61893	0.74533	0.74617
Standard Error (Q/Ha)			3.13543	3.17164	2.38869	2.00777	2.03372
Standard Variance $(Q/Ha)^2$			9.83091	10.05930	5.70584	4.03113	4.13602

Standard Deviation of Yields = 3.67594 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1953, 1955-1975
Meteorological Normals Based on 1933-1975

June 1977

SASKATCHEWAN 9

Region

Saskatchewan Crop Region 9

P.E.T. A = .876
P.E.T. I = 23.248

June Daylength = 1.3905
July Daylength = 1.3431
August Daylength = 1.2011

Latitude = 53°N

Variable	Deviation	Normal	Trend	April	May	June	July	August	September
Constant		1.00	7.87079	8.29670	8.02766	9.36129	10.89362	10.71341	10.60981
Linear Trend, 1930-1975		45.00	0.22391	0.20517	0.21635	0.21295	0.13643	0.14296	0.14072
Fallow Prec 20 Mo - Apr	DFN	570.79		0.00839	0.01098	0.00777	0.00699	0.00695	0.00871
Apr Min Temp (°C)	DFN	-4.14		0.23445	0.26939	0.29059	0.09837	0.12364	0.16269
May Max Temp (°C)	DFN	17.37			0.46149	0.65886	0.27993	0.13988	0.12408
Jun Prec - P.E.T. (mm)	DFN	-42.69				0.07879	0.06597	0.06656	0.06727
Jun Prec - P.E.T. (mm)	SDFN	-42.69				-0.00105	-0.00057	-0.00063	-0.00054
Jul Prec - P.E.T. (mm)	DFN	-60.03					0.06865	0.06907	0.06211
Jul Prec - P.E.T. (mm)	SDFN	-60.03					-0.00014	-0.00011	-0.00003
Aug Prec - P.E.T. (mm)	DFN	-50.64						-0.02452	-0.02909
Sep Min Temp (°C)	DFN	2.83							0.49486
R Squared			0.37907	0.40493	0.43425	0.77195	0.87424	0.89040	0.91354
Standard Error (Q/Ha)			3.68723	3.70340	3.65946	2.38884	1.82695	1.73193	1.56289
Standard Variance $(Q/Ha)^2$			13.59567	13.71514	13.39166	5.70658	3.33774	2.99957	2.44261

Standard Deviation of Yields = 4.62185 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1953, 1955-1975
Meteorological Normals Based on 1933-1975

June 1977

MANITOBA 1

Region

Manitoba Crop Region 1

P.E.T. A = .987
P.E.T. I = 30.536

June Daylength = 1.3460
July Daylength = 1.3049
August Daylength = 1.1800

Latitude = 50°N

Variable	Deviation	Normal	Trend	April	May	June	July	August	September
Constant		1.00	11.94026	11.10683	10.98083	11.67751	12.62765	13.37640	12.97186
Linear Trend, 1930-1975		45.00	0.09347	0.08467	0.08784	0.09352	0.06371	0.05069	0.04314
Fallow Prec 20 Mo - Apr	DFN	751.16		0.00424	0.00458	0.00386	0.00632	0.00685	0.00644
Fallow Prec 20 Mo - Apr	SDFN	751.16		0.00010	0.00011	0.00009	0.00008	0.00006	0.00007
May Max Temp (°C)	DFN	17.57			0.09460	0.15167	0.31077	0.41962	0.43671
Jun Prec - P.E.T. (mm)	SDFN	-38.24				-0.00053	-0.00042	-0.00058	-0.00061
Jul Prec - P.E.T. (mm)	DFN	-65.62					0.03678	0.04275	0.04211
Jul Prec - P.E.T. (mm)	SDFN	-65.62					-0.00033	-0.00039	-0.00040
Aug Prec - P.E.T. (mm)	DFN	-48.58						0.02780	0.02608
Sep Min Temp (°C)	SDFN	6.31							0.29360
R Squared			0.17276	0.28081	0.28604	0.38222	0.52158	0.62810	0.68472
Standard Error (Q/Ha)			2.64846	2.53530	2.56091	2.41597	2.18955	1.96040	1.83390
Standard Variance $(Q/Ha)^2$			7.01433	6.42777	6.55824	5.83690	4.79415	3.84318	3.36320

Standard Deviation of Yields = 2.87527 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1953, 1955-1962, 1964-1975
Meteorological Normals Based on 1933-1975

June 1977

MANITOBA 2

Region

Manitoba Crop Region 2

P.E.T. A = .987
P.E.T. I = 30.536

June Daylength = 1.3460
July Daylength = 1.3049
August Daylength = 1.1800

Latitude = 50°N

Variable	Deviation	Normal	Trend	April	June	July	August
Constant		1.00	10.04430	10.01057	10.98120	11.92099	12.04536
Linear Trend, 1930-1975		45.00	0.19336	0.19413	0.18750	0.17224	0.17768
Apr Min Temp (°C)	DFN	-2.86		0.45447	0.38149	0.17484	0.15008
Jun Prec - P.E.T. (mm)	DFN	-29.21			0.01824	0.01265	0.00293
Jun Prec - P.E.T. (mm)	SDFN	-29.21			-0.00044	-0.00042	-0.00032
Jul Prec - P.E.T. (mm)	DFN	-63.30				0.01553	0.02251
Jul Prec - P.E.T. (mm)	SDFN	-63.30				-0.00060	-0.00059
Aug Prec - P.E.T. (mm)	DFN	-48.30					0.03084
Aug Prec - P.E.T. (mm)	SDFN	-48.30					-0.00033
R Squared			0.47873	0.53411	0.64745	0.70364	0.78210
Standard Error (Q/Ha)			2.59611	2.48561	2.21990	2.09264	1.84795
Standard Variance $(Q/Ha)^2$			6.73978	6.17827	4.92797	4.37916	3.41493

Standard Deviation of Yields = 3.55165 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1955, 1955-1975
Meteorological Normals Based on 1933-1975

June 1977

MANITOBA 3

Region

Manitoba Crop Region 3

P.E.T. A = .967
P.E.T. I = 29.219

June Daylength = 1.3460
July Daylength = 1.3049
August Daylength = 1.1800

Latitude = 50°N

Variable	Deviation	Normal	Trend	April	June	July	August
Constant		1.00	9.18002	9.15534	9.93745	10.55902	10.64408
Linear Trend, 1930-1975		45.00	0.21568	0.21596	0.22015	0.20757	0.21029
Apr Min Temp (°C)	DFN	-2.93		0.53603	0.39127	0.29748	0.24396
Jun Prec - P.E.T. (mm)	DFN	-24.05			0.03699	0.03432	0.02827
Jun Prec - P.E.T. (mm)	SDFN	-24.05			-0.00040	-0.00036	-0.00031
Jul Prec - P.E.T. (mm)	DFN	-64.88				0.00767	0.00970
Jul Prec - P.E.T. (mm)	SDFN	-64.88				-0.00042	-0.00032
Aug Prec - P.E.T. (mm)	DFN	-45.43					0.01825
Aug Prec - P.E.T. (mm)	SDFN	-45.43					-0.00024
R Squared			0.53176	0.59942	0.76859	0.78589	0.81917
Standard Error (Q/Ha)			2.60407	2.43926	1.90343	1.88248	1.78164
Standard Variance $(Q/Ha)^2$			6.78116	5.94999	3.62304	3.54372	3.17423

Standard Deviation of Yields = 3.75884 (Q/Ha)

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Measured in Quintals per Hectare

Yields Based on 1933-1953, 1955-1975
Meteorological Normals Based on 1933-1975

June 1977