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WHEAT YIELD MODELS FOR THE U.S.S.R.

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WHEAT YIELD ESTIMATION MODELS

FOR THE U.S.S.R.

Clarence M. Sakamoto and Sharon K. LeDuc

Introduction

The Union of Soviet Socialist Republics (U.S.S.R.) is the leading wheat producer in the world. However, U.S.S.R. production has been highly variable, primarily because of weather conditions. Much of the U.S.S.R. wheat is grown under extreme climatic conditions.

This study reports on a quantitative model determining the relationship between weather conditions and wheat yield in the U.S.S.R. The purpose of the model is to provide reliable forecasts on the size of the U.S.S.R. wheat harvest earlier than do currently available reports.

Since wheat is grown in many areas of the U.S.S.R. under diverse climatic and cultural conditions, separate models were developed for different geographic locations. The basic geographic area represented by a model was a crop region. Because of data limitations occasionally two or more crop regions were combined.

Separate models are developed for spring wheat and for winter - the two major wheat classes in the U.S.S.R. Differences in yield potential and responses to stress conditions and cultural improvements necessitate models for each class.

The basic yield data were obtained from various sources for the period 1958-1973 (CIA, Personal Communication; Manellya, et. al., 1972; Economic Research Service, USDA, Personal Communication). A problem of unknown scope with U.S.S.R. statistics is the practice of reporting grain yields and production in "bunker weight" - the weight of the grain as it comes from the combine (Pope, et. al., 1973). That is, the data represent grain containing varying amounts of moisture and foreign matter, depending on weather conditions during harvest. Hence, some annual variation would be expected if "bunker weight" were converted to a standard measure representing usable grain.

The U.S.S.R. was divided into 33 regions. Most of these include more than one Oblast (Figure 1). Production and acreage information were available for each Oblast. The yield for a region was calculated by dividing the total production by the total acreage in each region. In some cases only yield data, not acreage and production, were available for the latter years, particularly for 1972 and 1973. Wheat yield data for the period 1947-1969 are published (Manellya, et. al., 1972) for parts of the U.S.S.R., but corresponding climatic data are not readily available.

The climatological data base 1961-1973 was developed by ETAC, the Environmental Technical Application Branch of the Air Force. For the period 1961-1965, the meteorological data were extracted by hand from weather maps. The data bases contain the unweighted average of the observations within a region. Since it was desirable to increase the sample size, the data base for the period 1957 through 1961 was estimated with the use of World Meteorological Organization (WMO) climatological

Figure 1. Crop regions showing areas for which wheat models have been developed. The hatched lines within a darkened line area show the inclusion of more than one crop region in a single model.

records (USDC, ESSA, 1966, 1967). The data were plotted by computer and analyzed subjectively for each region through the precipitation isohyets and temperature isotherms for each month of the years covered.

Factors Affecting Wheat Production

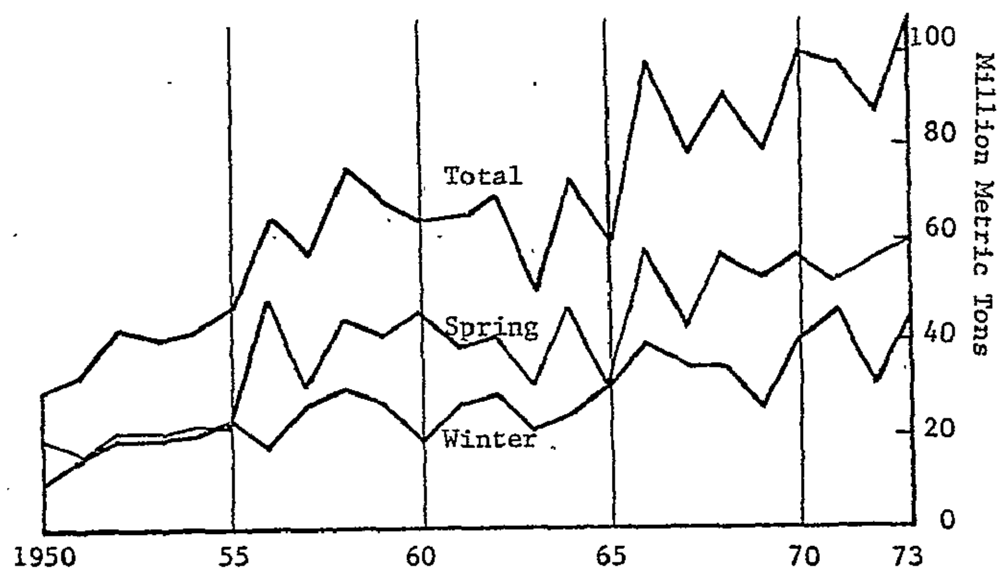
The U.S.S.R. produces approximately one-fourth of the total world wheat (Bureau of Agricultural Economics, 1974). Winter wheat is grown primarily in European U.S.S.R. while spring wheat is the principal wheat grown in Asiatic U.S.S.R. Production of all wheat increased 40 percent from 1959-1964 to 1969-1973. However, planted acreage and harvested acreage has changed little since 1955 (Figure 2). The increased production is, therefore, due to an upward trend in yield (Manellya, et. al., 1972). Approximately 75 percent of the total wheat-sown area is planted to spring wheat, the remainder to winter wheat. Figure 2 shows the total area sown to each during the period 1950 through 1973. During those years where winterkill was substantial, e.g., 1960, 1969, replanting to spring wheat was evident. The variation in harvested acreage has been associated with the variability in weather (e.g., 1960, 1969, 1972). Winterkill and moisture stress are two major weather hazards that reduce wheat production in the Soviet Union.

Since 1949 both spring and winter wheat have shown an upward yield trend (Figures 3 and 4). Factors contributing to higher yield include improved varieties, increased mechanization, greater fertilizer use, irrigation of more acres, application of pesticides on more hectares, etc.

The bulk of the Russian wheat is harvested from June through August. Winter wheat is usually harvested earlier than spring wheat.

USSR WHEAT

PRODUCTION



AREA SOWN

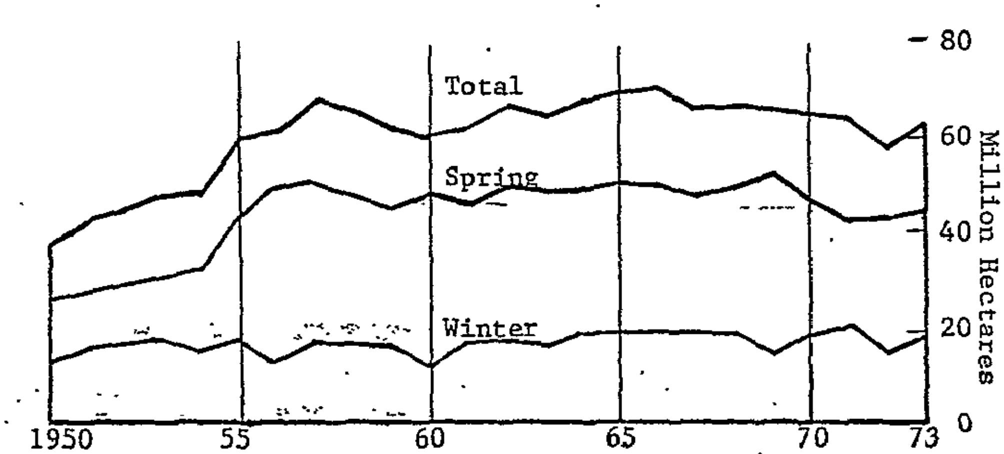


Figure 2. March of production and spring and winter wheat sown area in the U.S.S.R. from 1950-1973 (source: CIA, 1974).

RSFSR SPRING WHEAT YIELDS

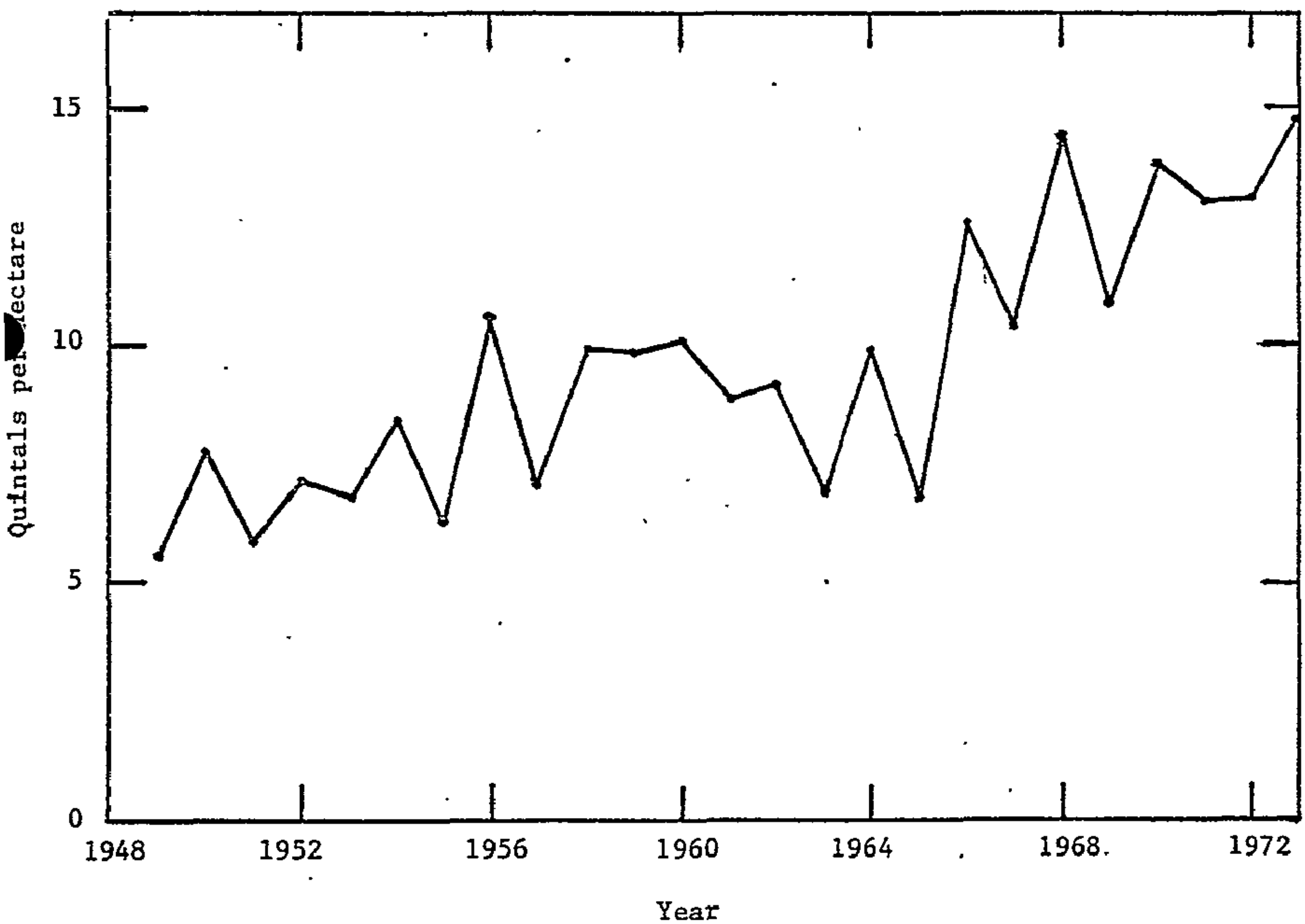


Figure 3. Spring wheat yield in the Russian Soviet Federated Socialist Republic (RSFSR), 1949-1972 (data: Manellya, et. al., 1972).

RSFSR WINTER WHEAT YIELDS

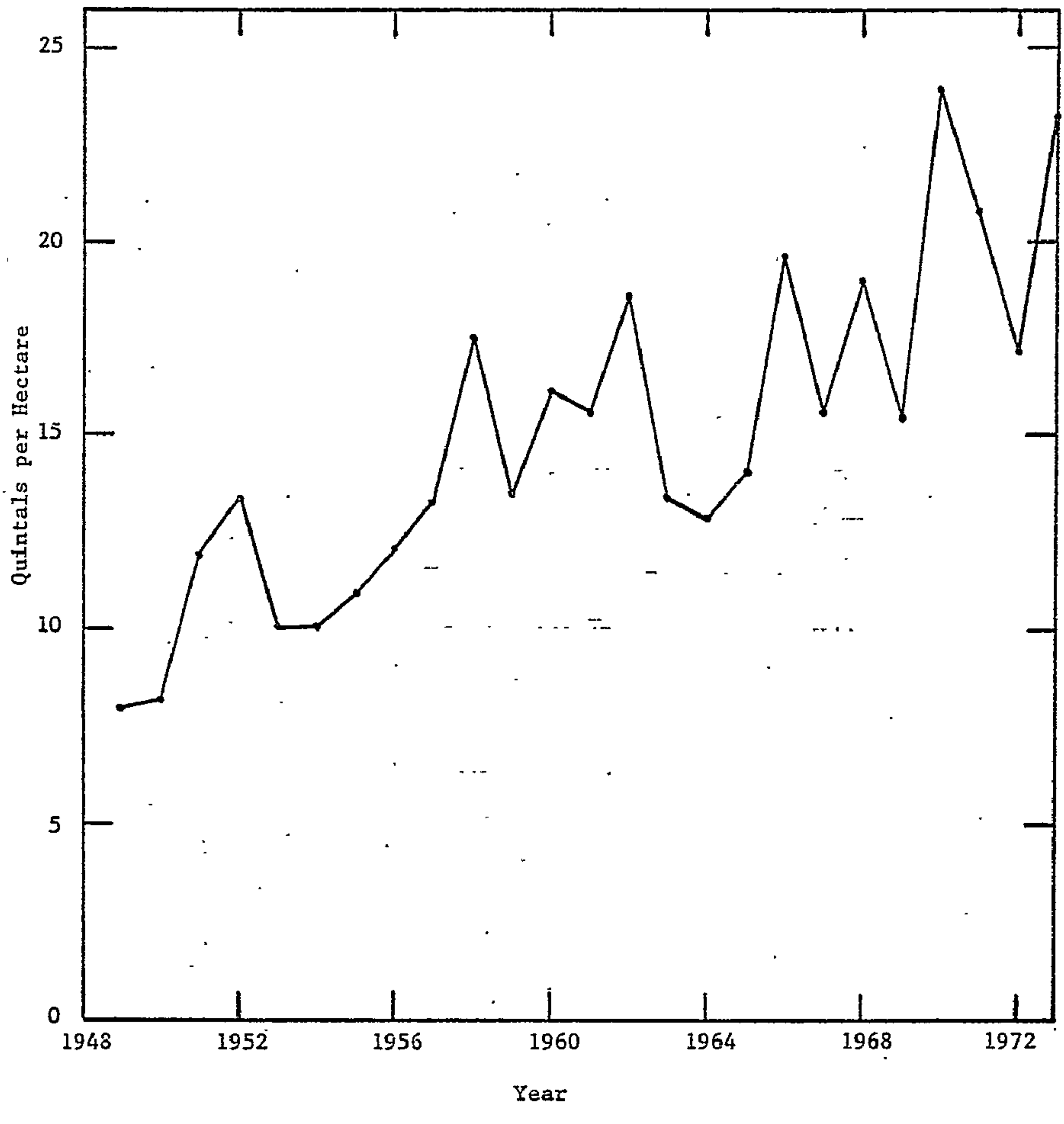


Figure 4. Winter wheat yield in the Russian Soviet Federated Socialist Republic (RSFSR), 1949-1972 (data: Manellya, et. al., 1972).

The wheat-growing area in the U.S.S.R. covers a wide range of climate. The distance between the northern and southern latitudes spans over a thousand miles. Other features such as mountains and distance from oceans vary widely. Consequently, each region has unique perennial weather-related problems that affect wheat yield. For example, regions close to the Black Sea, 6, 7, and 9, are influenced by the moderating effect of the waters, which can lead to wheat rust problems. In Regions 13 and 14, excessive moisture during spring is a major concern. In Kazakhstan and regions north and east of the Caspian Sea, drought and sukhovei (a hot dry wind) onset are perennial yield reducing problems. East of the Ural Mountains in Regions 20, 26, and 27, excessive spring rains affect planting, and fall frosts affect the ripening of grain.

The time of moisture stress relative to the growth stage affects the degree of yield reduction. If moisture stress is experienced at the heading through flowering phase and the filling phase, yield is reduced substantially. Yield is also reduced when stress occurs during earlier growth stages, but reduction is not as great as when stress occurs during the heading period (Bauer, 1972; Panomarev, 1962).

High temperature can also be detrimental to wheat production. Temperatures above 32^{o}C (90^{o}F) can hurt wheat crop yield during critical periods such as flowering (Jensen and Lund, 1971; Kogan, 1966; Panomarev, 1962). Low temperatures affect the wheat plant differently depending on the growth stage and variety. Areas with a continental climate, particularly in European U.S.S.R., have the highest probability of low temperature damage. A combination of poor snow cover, low humidity and strong winds can cause extensive damage. For example, as much as

35 percent of the fall-sown winter grains was estimated to have been winterkilled in 1969 (CIA, 1974). The Soviets have suggested that snow cover should be at least 30 cm in European U.S.S.R. and 40 cm in Asiatic U.S.S.R. to provide protection from the temperature hazards of winter (CIA, 1974). Winter wheat can withstand a temperature of -40°C (-40°F) if the crop is hardened prior to the low temperature and protected by the snow cover. Without a snow cover, the same crop could withstand temperatures as low as -32°C (-25°F) (Martin and Leonard, 1949). Martin and Leonard also indicate that spring wheat can withstand temperatures as low as -9°C (15°F). However, temperatures a degree or two below freezing during the period from heading through grain development can reduce yield substantially. The extent to which yield is affected depends upon the duration of the low temperature as well as the variety of wheat.

A phenomenon which can also reduce wheat yield in a short period of time, from a few hours to a few days, is the sukhovei - hot dry winds that occur most frequently in the southern and southeastern sections of European U.S.S.R., in Kazakhstan east of the Volga, and in Western Siberia. On a sukhovei day, the relative humidity frequently drops below 30 percent; evapotranspiration increases to a point where the plant even wilts although moisture is present in the soil. The relative humidity at night during a sukhovei is sometimes lower than during a drought (Borisov, 1959). The frequency of the sukhovei resembles a drought frequency chart in scope as well as in percentage (Figure 5 after Alpatev in Vitkevich 1960).

Most of the precipitation in the U.S.S.R. falls during the months of April through September (Figure 6). In the northern Belorussia and Central Regions, the maximum occurs late in July and August, which hampers

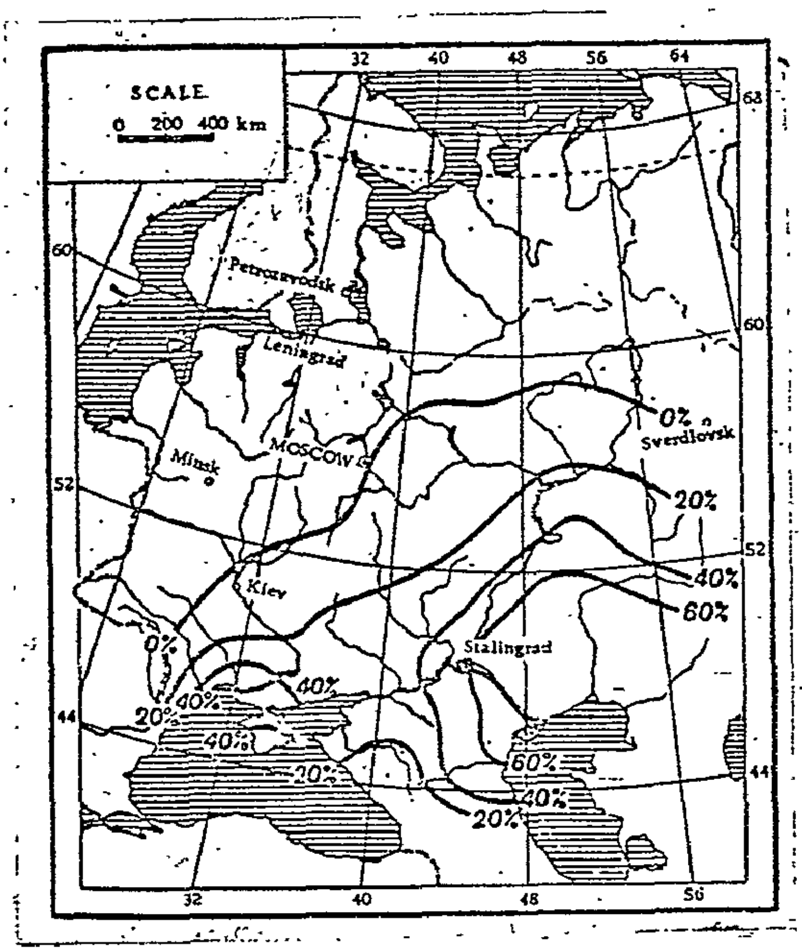
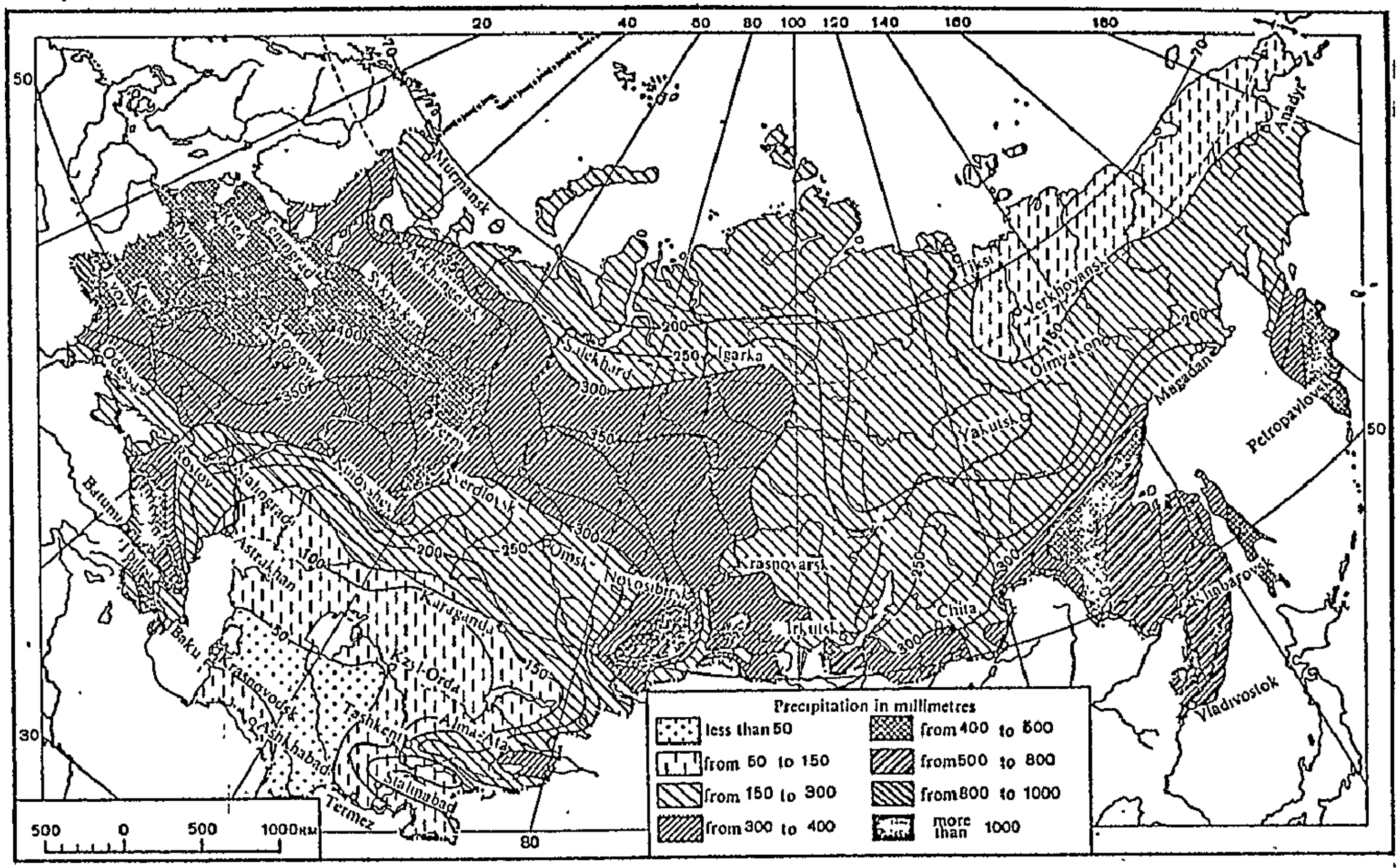


Figure 5. Drought Frequency Chart in the U.S.S.R. (source: Vitkevich, 1960).



Distribution of precipitation in the warm period of the year [April-Sept.]

Figure 6. Average precipitation during the warm period, April through September (source: Borisov, 1959).

harvesting operations. Also, in these areas low temperatures and frost can reduce yield substantially (Jakovlev, 1973).

Although rainfall during a critical period is beneficial, excessive rainfall can have a depressing effect on yield. Bogdanov (1965), for example, found that for spring wheat excessive rainfall from the period following flowering to waxy ripe or hard dough stage reduced yield in the central non-Chernozem region. In this report, these areas include Regions 11 and 12 of Figure 1. Jakovlev (1973) also reported that in northern Kazakhstan high yields were characterized by above normal May-July rainfall (175-185 mm) with temperatures below 20°C in July.

Winter wheat productivity is affected not only by spring and summer weather, but also by precipitation during the preceding fall and winter, which adds to the soil moisture reserve and supplements the spring and summer rainfall. If the soil moisture reserve is low and May precipitation is less than 12 mm in the Steppe Regions of Ukraine and Northern Caucasus, winter wheat yield will be low (Ulanova, 1966). Yields may also be lowered if May precipitation is excessive (more than 80 mm). However, if soil moisture reserve is low, high yields are possible if May precipitation is high.

The Regression Models

A mathematical model was developed for each region regressing wheat yield against a time variable as a surrogate for factors affecting yield trend and a set of weather variables measuring the influence of weather. The basic general model for a particular region which may include several subregions is:

$$Y_{ij} = \alpha_j + \beta T_i + \sum_{k=1}^{n} \gamma_{jk} W_{ijk} + \varepsilon_{ij}$$

where:

i = year

j = subregion, $j = 1, 2, \ldots, m$ and m differs with models

k = weather variable, $k = 1, \ldots, n$ and n differs with models

Y_{ij} = estimated yield for the ith year and jth subregion

α_j = constant for the jth subregion

β = coefficient for trend, T

T_i = trend for ith year (1958=1, 1959=2, ..., 1973=16)

γ_{jk} = coefficient for kth weather variable W_{ijk} where:

These are the aridity index, temperature anomaly and/or precipitation anomaly or the square of one of these variables (these weather variables are based on monthly data only). The kth weather variable is not the same function for each model.

n = the number of distinct weather variables and will vary by region

ε_{ij} = unexplained variation of the ith year and jth subregion

In most cases a linear trend is included in the model, but where a time variable failed to improve the predictive equation the coefficient β was then assumed to be zero.

The Weather Variables

The basic weather data, consisting of monthly temperature and monthly precipitation, are used to derive monthly weather variables consisting of an aridity index, a monthly temperature departure from normal, and a monthly precipitation departure from normal. The aridity index, also expressed as the departure from normal where normal is the average value (usually 1958-1973), is defined as monthly precipitation minus potential evapotranspiration (P.E.T.). Thornthwaite's procedure (Palmer and Havens, 1958; Thornthwaite, 1948) for estimating potential evapotranspiration is utilized. The formula for P.E.T. is:

$$P.E.T. = 16.0\ \{10\ (T)_m/I\}^a$$

where P.E.T. = monthly potential evapotranspiration in millimeters for the month m.

$(T)_m$ = monthly mean temperature (^oC) for month m

$$I = \text{heat index} = \sum_{m=1}^{12} h_m$$

and $h_m = \{(T)_m/5\}^{1.514}$

for m=1 (January) through m=12 (December)

$$a = 6.75 \times 10^{-7}I^3 - 7.71 \times 10^{-5}I^2 + 1.79 \times 10^{-2} + 0.49$$

Expressions for a and h_m were determined empirically by Thornthwaite (1948). I is a heat index which is a constant for a given location. Daylight corrections are applied as a fraction of 12 hours.

In some cases, the departure of the observed precipitation P_m, from the average precipitation, $\overline{P}_m$, was used in lieu of the aridity index. In most cases the first weather variable to enter the model is typically the accumulated preseason moisture, generally from September through March of the growing season.

The monthly temperature departure from normal is defined as $T_m - \overline{T}_m$ where T_m is the observed temperature and $\overline{T}_m$ is the average temperature over the data period for month m. The data period was generally 1958-1973.

Estimates of wheat yield are desired as early in the season as possible. Hence, truncated models were developed using as much weather data as is available at the truncated period. For example, a truncated winter wheat model for March used weather coefficients through the month of March.

Selection of Weather Variables

In selecting the final model for a region, the four basic guidelines used were:

1. The coefficient signs are agronomically feasible.
2. The standard error is reduced with each truncation.
3. The variable selected in the initial truncation is maintained for subsequent truncation.
4. The final model explains as much of the yield variability as possible.

The selection of weather variables usually began with determining a preseason variable such as total precipitation from September through April (preseason moisture) for spring wheat. The months included for preseason moisture varied with regions (e.g., September through March or November through March). In some areas such as the Kazakhstan regions, preseason accumulated precipitation failed to show any statistical importance. This is probably due to the relative dryness of the arid and semi-arid zone where rainfall prior to planting has evaporated and is not available in the subsoil for later use.

In the winter wheat areas, winter temperatures are important to the winterkill problem. This leads to the problem of determining what constitutes the winter months. For example, in those regions in the European U.S.S.R. near the Black Sea the winter months include January and February for the assessment of winter temperature. Farther to the interior of the U.S.S.R., these months include November or December through March. Different months were tested to determine the best fit of a winter temperature variable to yield.

The aridity index value, precipitation minus P.E.T., which combines both temperature and precipitation, was generally tried first for the spring months. In some cases where this aridity index failed to show its significance, precipitation was included for analysis. The inclusion of only precipitation for the spring and summer months indicates that this variable was a better indicator of yield response than the aridity index.

April temperature was often important in wheat growing areas. Generally speaking, higher temperature is associated with the enhancement of regrowth of the winter wheat and the establishment of spring wheat. Where the spring temperature shows a negative coefficient (e.g., Region 13) this can be interpreted to mean that too early a warming period during April will enhance vegetative growth at the expense of grain development in winter wheat.

In some cases the introduction of a variable increased the standard error of estimate slightly, but this variable was maintained if it was determined to be agronomically reasonable and the addition of another variable for the subsequent truncation period increased the fit of the data to the model. This would not have occurred if the variable in the previous truncation period had been removed.

The description of each model is included in the Appendix. A list of all models for specified regions is also attached. The darkened outline for an area indicates a particular model which may include more than one region. If more than one region is included in a model, this is noted by hatched lines (see Figure 1).

Summary

The models for the U.S.S.R. have been developed with limited meteorological and yield data.

It is suggested that those using these models apply a "flagging" system to detect extreme temperatures and/or precipitation. A suggested flagging system might include flagging precipitation values greater than the 90th percentile and/or less than the 10th percentile; temperature values greater than the 95th percentile and/or less than the 5th percentile might also be flagged. In these instances, the value for the 10th or 90th percentile for precipitation or the 5th or 95th percentile for temperature might be used in lieu of the extreme value. Furthermore, it is suggested that yield results less than zero be assumed to be zero.

Additional years should help to stabilize the coefficients involved in the equation. The extension of the time trend three years into the future is dangerous because of the size of the coefficient and the potential instability.

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APPENDIX

U.S.S.R. WINTER WHEAT MODELS

Baltics-Belorussia

1. Baltics
2. Belorussia

North Ukraine

3. West Ukraine
4. North Central Ukraine
5. Northeast Ukraine

Ukraine-Krasnodar

6. Eastern Ukraine
7. Southern Ukraine
9. Krasnodar

Moldavia

8. Moldavia

Caucasus-Volga

10. Northeast Caucasus
17. Lower Volga

Black Soil Zone

11. West Black Soil Zone
12. East Black Soil Zone

Central District

13. Central Region

Volga-Vyatsk

14. Volga-Vyatsk

Upper Volga

15. Upper Volga

Middle Volga

16. Middle Volga

Northwest Urals

18. Northwest Urals

Transcaucasus

28. Transcaucasus

South Kazakhstan

29. South Kazakhstan

Central Asia

30. Central Asia

Northwest

33. Northwest

APPENDIX

U.S.S.R. SPRING WHEAT MODELS

Black Soil Zone

11. West Black Soil Zone
12. East Black Soil Zone

Central District

13. Central Region

Volga-Vyatsk

14. Volga-Vyatsk

Upper Volga

15. Upper Volga

Middle Volga

16. Middle Volga

Caucasus-Volga

10. Northeast Caucasus
17. Lower Volga

Northwest Urals

18. Northwestern Urals

Southern Urals-Western Kazakhstan

19. Southern Urals
21. Western Kazakhstan

Northeastern Urals

20. Northeastern Urals

Northeast Kazakh

22. Kustanay
23. Tselinograd
24. Northern Kazakhstan
25. Pavlodar

Siberia-Altai

26. Western Siberia
27. Altai Krai

South Kazakhstan

29. South Kazakhstan

Central Asia

30. Central Asia

Eastern Siberia

31. Eastern Siberia

Far East

32. Far East

Northwest

33. Northwest

BALTICS-BELORUSSIA WINTER WHEAT COVARIANCE MODEL

Region

Baltics - Crop Region 1
Belorussia - Crop Region 2

P.E.T. A = .946
P.E.T. I = 27.816

April Daylength = 1.1674
May Daylength = 1.3374
June Daylength = 1.4254

Latitude = 55°N

Crop Region 1 Constant = 1 if Data from Crop Region 1; Otherwise 0

Variable	Deviation	Normal	Trend	March	April	May	June
Overall Constant		1.00	4.33592	4.56263	4.88144	4.82387	4.79744
Region 1 Constant		1.00	2.81226	2.34473	2.20686	2.37189	2.42756
Linear Trend (1958-1973)		16.00	1.10882	1.10965	1.08025	1.07731	1.07715
Dec-Mar Avg Temp ($^{\circ}$C)	DFN	-4.11		0.54305	0.63471	0.69105	0.68059
Apr Prec - P.E.T. (mm)	DFN	2.23			0.03842	0.03889	0.04869
May Prec - P.E.T. (mm)	DFN	-31.64				-0.02818	-0.02756
Jun Prec - P.E.T. (mm)	DFN	-56.21					0.02180
R Squared			0.81682	0.85246	0.86025	0.86928	0.87596
Standard Error (Q/Ha)			2.63715	2.40863	2.38720	2.35275	2.33725
Standard Variance (Q/Ha)			6.95458	5.80150	5.69874	5.53542	5.46273

Standard Deviation of Yields = 5.95955 Q/Ha

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

Yields and Climatic Data are Pooled Over Crop Regions 1 and 2
Yields Based on 1958-1973
Meteorological Normals Based on 1958-1973

NORTH UKRAINE WINTER WHEAT COVARIANCE MODEL

Region

West Ukraine - Crop Region 3
North Central Ukraine - Crop Region 4
Northeast Ukraine - Crop Region 5

P.E.T. A = 1.030
P.E.T. I = 33.428

April Daylength = 1.1393
May Daylength = 1.2773
June Daylength = 1.3460

Latitude = 50°N

Crop Region 3 Constant = 1 if Data from Crop Region 3; Otherwise 0
Crop Region 4 Constant = 1 if Data from Crop Region 4; Otherwise 0

Variable	Deviation	Normal	Trend	March	April	May	June
Overall Constant		1.00	14.02232	17.03209	16.91113	17.67622	19.26082
Region 3 Constant		1.00	-1.12029	-4.01435	-4.56768	-5.32192	-6.73875
Region 4 Constant		1.00	0.41235	-1.34084	-1.39607	-1.50568	-1.53973
Linear Trend (1958-1973)		16.00	0.90861	0.84046	0.85960	0.83308	0.74242
Sep-Mar Prec (mm)	DFN	287.65		0.00779	0.00595	0.00476	0.00371
Dec-Mar Temp (°C)	DFN	-2.96		1.31408	1.38943	1.32271	1.11158
Dec-Mar Temp (°C)	SDFN	-2.96		-0.23401	-0.19124	-0.14792	-0.09266
Apr Prec - P.E.T. (mm)	DFN	-6.98			0.03334	0.04418	0.01664
May Prec - P.E.T. (mm)	DFN	-36.72				0.02763	0.04871
May Prec - P.E.T. (mm)	SDFN	-36.72				-0.00046	-0.00063
Jun Prec - P.E.T. (mm)	DFN	-52.52					0.03712
Jun Prec - P.E.T. (mm)	SDFN	-52.52					-0.00028
R Squared			0.58101	0.79652	0.80477	0.82606	0.84547
Standard Error (Q/Ha)			3.75913	2.71383	2.69128	2.60628	2.52388
Standard Variance (Q/Ha)			14.13103	7.36489	7.24300	6.79269	6.36995

Standard Deviation of Yields = 5.61906 Q/Ha

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

Yields and Climatic Data are Pooled over Crop Regions 3, 4, and 5
Yields Based on 1958-1973
Meteorological Normals Based on 1958-1973

UKRAINE-KRASNODAR WINTER WHEAT COVARIANCE MODEL

Region

Eastern Ukraine - Crop Region 6
Southern Ukraine - Crop Region 7
Krasnodar - Crop Region 9

P.E.T. A = 1.206 | April Daylength = 1.1251 | Latitude = 47°N
P.E.T. I = 45.130

Crop Region 6 Constant = 1 if Data from Crop Region 6; Otherwise 0
Crop Region 7 Constant = 1 if Data from Crop Region 7; Otherwise 0

Variable	Deviation	Normal	Trend	February	March	April
Overall Constant		1.00	22.08902	18.13271	17.84735	17.03027
Region 6 Constant		1.00	-6.06706	-1.82993	-1.06709	-0.80185
Region 7 Constant		1.00	-5.33688	-4.69991	-3.45187	-3.16404
Linear Trend (1958-1973)		15.00	0.56707	0.92905	0.87673	0.95955
Jan-Feb Temp (°C)	DFN	-2.31		1.26688	1.15271	1.21937
Jan-Feb Temp (°C)	SDFN	-2.31		-0.06415	-0.06032	-0.06372
Sep-Mar Prec (mm)	DFN	302.67			0.01385	0.01332
Apr Prec - P.E.T. (mm)	DFN	-11.28				0.03454
R Squared			0.46541	0.76945	0.79243	0.80735
Standard Error (Q/Ha)			4.09730	2.75885	2.65198	2.58917
Standard Variance (Q/Ha)			16.78789	7.61124	7.03298	6.70382

Standard Deviation of Yields = 5.40947 Q/Ha

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

Yields and Climatic data are Pooled Over Crop Regions 6, 7, and 9
Yields Based on 1958-1972
Meteorological Normals Based on 1958-1972

MOLDAVIA WINTER WHEAT MODEL

Region

Moldavia - Crop Region 8

P.E.T. A = 1.186
P.E.T. I = 43.795

March Daylength = .9808
April Daylength = 1.1251

Latitude = 47°N

Variable	Deviation	Normal	Trend	February	March	April	June	July
Constant		1.00	10.49481	9.09938	8.33258	7.38836	6.97522	4.65335
Linear Trend (1958-1973)		16.00	1.20124	1.36541	1.45563	1.56671	1.61532	1.88847
Jan-Feb Avg Temp (°C)	DFN	-2.26		1.25431	1.20052	1.25488	0.84182	0.84113
Mar Prec - P.E.T. (mm)	DFN	20.81			-0.06288	-0.07146	-0.14263	-0.10165
Apr Prec - P.E.T. (mm)	DFN	-14.21				0.06763	0.06089	0.08502
Jun Temp (°C)	DFN	18.86					-2.23464	-1.39325
Jul Prec (mm)	DFN	60.63						-0.07373
R Squared			0.50283	0.63447	0.66253	0.71022	0.76977	0.80253
Standard Error (Q/Ha)			5.88632	5.23781	5.23821	5.06981	4.73951	4.62680
Standard Variance (Q/Ha)			34.64873	27.43462	27.43881	25.70300	22.46297	21.40732

Standard Deviation of Yields = 8.06514 Q/Ha

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

Yields Based on 1958-1973
Meteorological Normals Based on 1958-1973

May 1977

CAUCASUS-VOLGA WINTER WHEAT COVARIANCE MODEL

Region

Northeast Caucasus - Crop Region 10
Lower Volga - Crop Region 17

P.E.T. A = 1.184 — May Daylength = 1.2573 — Latitude = 48°N
P.E.T. I = 43.641

Crop Region 10 Constant = 1 if Data from Crop Region 10; Otherwise 0

Variable	Deviation	Normal	Trend	March	April	May
Overall Constant		1.00	14.35914	16.63994	16.77922	18.16074
Region 10 Constant		1.00	1.35574	-2.47534	-2.55532	-2.52471
Sep-Mar Prec (mm)	DFN	233.75		0.02834	0.02759	0.02877
Nov-Mar Temp (°C)	DFN	-2.98		1.12799	0.92628	0.74880
Nov-Mar Temp (°C)	SDFN	-2.98		-0.06090	-0.09846	-0.10528
Apr Temp (°C)	DFN	9.17			0.50509	0.61397
Apr Temp (°C)	SDFN	9.17			0.03074	-0.06899
May Prec - P.E.T. (mm)	DFN	-57.03				0.05800
May Prec - P.E.T. (mm)	SDFN	-57.03				-0.00141
R Squared			0.02583	0.52925	0.56642	0.70205
Standard Error (Q/Ha)			4.32000	3.19291	3.20685	2.79479
Standard Variance (Q/Ha)			18.66241	10.19468	10.28391	7.81085

Standard Deviation of Yields = 4.29508 Q/Ha

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

Yields and Climatic Data are Pooled Over Crop Regions 10 and 17
Yields Based on 1958-1971
Meteorological Normals Based on 1958-1971

BLACK SOIL ZONE WINTER WHEAT COVARIANCE MODEL

Region

West Black Soil Zone - Crop Region 11
East Black Soil Zone - Crop Region 12

P.E.T. A = 1.021 May Daylength = 1.2880 Latitude = 51°N
P.E.T. I = 32.810

Crop Region 12 Constant = 1 if Data from Crop Region 12; Otherwise 0

Variable	Deviation	Normal	Trend	February	March	April	May
Overall Constant		1.00	12.63277	9.72778	10.39611	11.10661	11.00843
Region 12 Constant		1.00	0.65617	1.80616	1.68806	1.85011	1.76580
Linear Trend (1958-1971)		14.00	0.47866	0.78932	0.70808	0.63560	0.64652
Jan-Feb Temp (°C)	DFN	-7.76		0.84960	0.64729	0.36669	0.32586
Mar Temp (°C)	DFN	-3.14			0.32550	0.70083	0.67848
Apr Prec (mm)	DFN	36.00				0.03461	0.03232
Apr Prec (mm)	SDFN	36.00				0.00262	0.00274
Apr Temp (°C)	SDFN	6.60				-0.17461	-0.16711
May Prec - P.E.T. (mm)	DFN	-43.95					0.01999
R Squared			0.22628	0.62085	0.63946	0.75049	0.77045
Standard Error (Q/Ha)			3.83018	2.73651	2.72588	2.43180	2.39308
Standard Variance (Q/Ha)			14.67027	7.48847	7.43044	5.91366	5.72683

Standard Deviation of Yields = 4.19001 Q/Ha

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

Yields and Climatic Data are Pooled Over Crop Regions 11 and 12
Yields Based on 1958-1971
Meteorological Normals Based on 1958-1971

CENTRAL DISTRICT WINTER WHEAT MODEL

Region

Central District - Crop Region 13

P.E.T. A = .937 May Daylength = 1.3517 Latitude = 56^{o}N
P.E.T. I = 27.226

Variable	Deviation	Normal	Trend	March	April	May
Overall Constant		1.00	6.98680	6.61694	7.43347	8.08181
Linear Trend (1958-1973)		16.00	0.65394	0.69745	0.67756	0.62374
Dec-Mar Temp (°C)	DFN	-7.35		0.35037	0.33625	0.25120
Apr Temp (°C)	SDFN	5.31			-0.18615	-0.24105
May Prec - P.E.T. (mm)	DFN	-36.04				0.03500
R Squared			0.71230	0.77284	0.82751	0.86092
Standard Error (Q/Ha)			2.04810	1.88861	1.71292	1.60651
Standard Variance (Q/Ha)			4.19473	3.56687	2.93409	2.58087

Standard Deviation of Yields = 3.68892 Q/Ha

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

Yields Based on 1958-1973
Meteorological Normals Based on 1958-1973

VOLGA-VYATSK WINTER WHEAT MODEL

Region

Volga-Vyatsk - Crop Region 14

P.E.T. A = .914
P.E.T. I = 25.737

May Daylength = 1.3517
June Daylength = 1.4448

Latitude = 56°N

Variable	Deviation	Normal	Trend	April	May	June
Overall Constant		1.00	8.70076	9.91247	10.42161	10.92689
Linear Trend (1958-1973)		16.00	0.40203	0.42958	0.31702	0.25930
Apr Temp (°C)	DFN	3.81		0.18745	0.36502	0.50192
Apr Temp (°C)	SDFN	3.81		-0.27819	-0.19206	-0.02053
May Prec - P.E.T. (mm)	DFN	-39.41			0.05659	0.06963
Jun Prec - P.E.T. (mm)	DFN	-55.99				0.06491
Jun Prec - P.E.T. (mm)	SDFN	-55.99				-0.00118
R Squared			0.35399	0.57413	0.72518	0.83989
Standard Error (Q/Ha)			2.67641	2.34717	1.96935	1.66181
Standard Variance (Q/Ha)			7.16317	5.50921	3.87834	2.76161

Standard Deviation of Yields = 3.21701 Q/Ha

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

Yields Based on 1958-1973
Meteorological Normals Based on 1958-1973

UPPER VOLGA WINTER WHEAT MODEL

Region

Upper Volga - Crop Region 15

P.E.T. A = .965 | May Daylength = 1.3240 | Latitude = 54°N
P.E.T. I = 29.088 | June Daylength = 1.4074

Variable	Deviation	Normal	Trend	April	June
Overall Constant		1.00	8.68658	10.09648	10.31692
Linear Trend (1958-1971)		12.00	0.64203	0.70462	0.64266
Apr Temp (°C)	DFN	3.81		0.31508	0.32207
Apr Temp (°C)	SDFN	3.81		-0.42804	-0.37505
Jun Prec - P.E.T. (mm)	DFN	-66.26			0.04861
R Squared			0.44277	0.75727	0.84134
Standard Error (Q/Ha)			2.90232	2.09838	1.78825
Standard Variance (Q/Ha)			8.42344	4.40319	3.19785

Standard Deviation of Yields = 3.73550 Q/Ha

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

Yields Based on 1958-1971
Meteorological Normals Based on 1958-1971

MIDDLE VOLGA WINTER WHEAT MODEL

Region

Middle Volga - Crop Region 16

P.E.T. A = 1.058 May Daylength = 1.2994 Latitude = 52^{o}N
P.E.T. I = 35.238

Variable	Deviation	Normal	April	May
Overall Constant		1.00	16.20480	16.54855
Apr Temp (^{o}C)	DFN	6.23	0.96544	1.72873
Apr Temp (^{o}C)	SDFN	6.23	-0.39161	-0.46741
May Prec - P.E.T. (mm)	DFN	-59.29		0.16253
R Squared			0.33013	0.80749
Standard Error (Q/Ha)			3.98903	2.24280
Standard Variance (Q/Ha)			15.91238	5.03017

Standard Deviation of Yields = 4.48328 Q/Ha

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

Yields Based on 1958-1971
Meteorological Normals Based on 1958-1971

May 1977

NORTHWEST URALS WINTER WHEAT MODEL

Region

Northwest Urals - Crop Region 18

P.E.T. A = .874
P.E.T. I = 23.120

May Daylength = 1.3834
June Daylength = 1.4885
July Daylength = 1.4247

Latitude = 58°N

Variable	Deviation	Normal	March	April	May	June	July
Overall Constant		1.00	11.35794	12.07928	11.63479	12.01433	12.00717
Dec-Mar Temp (°C)	DFN	-11.68	0.07397	0.21037	0.25064	0.34808	0.34215
Dec-Mar Temp (°C)	SDFN	-11.68	-0.20443	-0.32667	-0.22040	-0.17960	-0.14958
Apr Temp (°C)	DFN	2.87		0.55667	0.67742	0.83435	0.93487
May Prec - P.E.T. (mm)	DFN	-44.75			0.03711	0.04858	0.05975
Jun Prec - P.E.T. (mm)	DFN	-61.52				-0.00761	-0.00407
Jun Prec - P.E.T. (mm)	SDFN	-61.52				-0.00064	-0.00091
Jul Prec - P.E.T. (mm)	DFN	-60.47					-0.01758
R Squared			0.29633	0.50815	0.69021	0.78888	0.82644
Standard Error (Q/Ha)			1.97784	1.75387	1.48802	1.45348	1.47342
Standard Variance (Q/Ha)			3.91186	3.07605	2.21420	2.11260	2.17097

Standard Deviation of Yields = 2.13270 Q/Ha

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

Yields Based on 1958-1969
Meteorological Normals Based on 1958-1973

TRANSCAUCASUS WINTER WHEAT MODEL

Region

Transcaucasus - Crop Region 28

P.E.T. A = 1.441
P.E.T. I = 60.315

June Daylength = 1.2463

Latitude = 41^{o}N

Variable	Deviation	Normal	Trend	April	May	June
Overall Constant		1.00	7.13531	7.48573	7.57169	7.64755
Linear Trend (1958-1974)		17.00	0.47916	0.48970	0.46731	0.47485
Apr Prec (mm)	DFN	26.82		-0.02195	-0.02818	-0.03459
Apr Prec (mm)	SDFN	26.82		-0.00340	-0.00252	-0.00208
May Temp (°C)	DFN	18.19			-0.31632	-0.05342
Jun Prec - P.E.T. (mm)	DFN	-106.97				0.02749
Jun Prec - P.E.T. (mm)	SDFN	-106.97				-0.00063
R Squared			0.76412	0.80493	0.81955	0.87758
Standard Error (Q/Ha)			1.38844	1.35629	1.35774	1.22506
Standard Variance (Q/Ha)			1.92776	1.83951	1.84345	1.50077

Standard Deviation of Yields = 2.76801 Q/Ha

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

Yields Based on 1958-1974
Meteorological Normals Based on 1958-1974

SOUTH KAZAKHSTAN WINTER WHEAT MODEL

Region

South Kazakhstan - Crop Region 29

P.E.T. I = 1.365
P.E.T. A = 55.497

May Daylength = 1.2066

Latitude = 42°N

Variable	Deviation	Normal	Constant	March	April	May	June
Overall Constant		1.00	10.45508	10.45508	10.70239	11.99482	11.88507
Dec-Mar Temp (°C)	DFN	0.44		0.20381	0.16862	0.10457	0.15290
Apr Temp (°C)	DFN	12.86			-0.62323	-0.16378	-0.21217
Apr Temp (°C)	SDFN	12.86			-0.12794	-0.08628	-0.06721
May Prec - P.E.T. (mm)	DFN	-44.62				0.06023	0.05791
May Prec - P.E.T. (mm)	SDFN	-44.62				-0.00121	-0.00115
Jun Temp (°C)	DFN	23.21					-0.47889
R Squared			0.00000	0.02432	0.14520	0.65295	0.66878
Standard Error (Q/Ha)			3.00576	3.06636	3.08301	2.13556	2.18812
Standard Variance (Q/Ha)			9.03459	9.40255	9.50495	4.56060	4.78788

Standard Deviation of Yields = 3.00576 Q/Ha

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

Yields Based on 1958-1974
Meteorological Normals Based on 1957-1974

CENTRAL ASIA WINTER WHEAT MODEL

Region

Central Asia - Crop Region 30

P.E.T. A = 1.421
P.E.T. I = 59.091

April Daylength = 1.0977
May Daylength = 1.1921

Latitude = 40°N

Variable	Deviation	Normal	Trend	March	April	May	June
Overall Constant		1.00	5.66360	5.20955	5.26420	5.53685	5.42305
Linear Trend (1958-1974)		17.00	0.29145	0.34190	0.33583	0.30553	0.31818
Nov-Mar Prec (mm)	DFN	241.71		0.01265	0.01185	0.00623	0.00739
Apr Prec - P.E.T. (mm)	DFN	24.17			0.00771	0.00129	0.00123
May Prec - P.E.T. (mm)	DFN	-52.30				0.01897	0.01828
Jun Temp (°C)	DFN	24.15					-0.15456
R Squared			0.55286	0.67740	0.69627	0.75215	0.75529
Standard Error (Q/Ha)			1.36695	1.20184	1.21019	1.13784	1.18088
Standard Variance (Q/Ha)			1.86856	1.44441	1.46456	1.29467	1.39448

Standard Deviation of Yields = 1.97934 Q/Ha

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

Yields Based on 1958-1974.
Meteorological Normals Based on 1958-1974

NORTHWEST WINTER WHEAT MODEL

Region

Northwest - Crop Region 33

P.E.T. A = .891
P.E.T. I = 24.247

May Daylength = 1.3834
June Daylength = 1.4885
July Daylength = 1.4247

Latitude = 58^{o}N

Variable	Deviation	Normal	Trend	March	May	June	July
Overall Constant		1.00	8.25618	8.07855	8.02580	8.17219	8.15096
Linear Trend (1958-1971)		14.00	0.32679	0.34996	0.35804	0.33897	0.36044
Sep-Mar Prec (mm)	DFN	281.71		-0.00462	-0.00359	-0.00303	0.00953
May Prec - P.E.T. (mm)	DFN	-31.18			-0.00764	-0.00919	-0.01702
Jun Prec - P.E.T. (mm)	DFN	-63.83				-0.00529	-0.01552
Jul Prec - P.E.T. (mm)	DFN	-61.54					-0.04188
R Squared			0.59864	0.60864	0.62479	0.63189	0.86430
Standard Error (Q/Ha)			1.21037	1.25354	1.29380	1.35924	0.88224
Standard Variance (Q/Ha)			1.46500	1.57136	1.67393	1.84753	0.77834

Standard Deviation of Yields = 1.82919 Q/Ha

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

Yields Based on 1958-1965 and 1967-1971
Meteorological Normals Based on 1958-1971

CAUCASUS-VOLGA SPRING WHEAT COVARIANCE MODEL

Region

Northeastern Caucasus - Crop Region 10
Lower Volga - Crop Region 17

P.E.T. A = 1.193
P.E.T. I = 44.247

May Daylength = 1.2573
July Daylength = 1.2826

Latitude = 48^{o}N

Variable	Deviation	Normal	Constant	April	May	June	July
Overall Constant		1.00	9.33175	9.26464	8.97282	8.94580	9.19142
Sep-Apr Prec (mm)	DFN	261.57		0.02714	0.02454	0.02924	0.03112
Sep-Apr Prec (mm)	SDFN	261.57		0.00002	0.00010	0.00014	0.00018
Apr Mean Temp (°C)	DFN	9.36		0.10724	0.41367	0.38757	0.30637
May Prec - P.E.T. (mm)	DFN	-57.92			0.07652	0.08253	0.07940
May Prec - P.E.T. (mm)	SDFN	-57.92			-0.00016	-0.00034	-0.00008
Jun Prec (mm)	DFN	46.47				-0.02531	-0.00874
Jul Prec - P.E.T. (mm)	DFN	-114.28					-0.01664
Jul Prec - P.E.T. (mm)	SDFN	-114.28					-0.00089
R Squared			0.00000	0.31240	0.59491	0.60645	0.67168
Standard Error (Q/Ha)			3.38297	2.96263	2.36683	2.38304	2.27791
Standard Variance (Q/Ha)			11.44451	8.77718	5.60186	5.67888	5.18885

Standard Deviation of Yields = 3.38297 Q/Ha

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

Yields and Climatic Data are Pooled Over Regions 10 and 17
Yields Based on 1958-1972
Meteorological Normals Based on 1958-1972

BLACK SOIL ZONE SPRING WHEAT COVARIANCE MODEL

Region

West Black Soil Zone - Crop Region 11
East Black Soil Zone - Crop Region 12

P.E.T. A = 1.021 June Daylength = 1.3600 Latitude = 51°N
P.E.T. I = 32.810 July Daylength = 1.3170

Variable	Deviation	Normal	Trend	February	April	May	June	July
Overall Constant		1.00	6.95206	7.54990	7.86415	9.01441	7.35854	6.60397
Linear Trend (1958-1971)		14.00	0.80050	0.72078	0.67888	0.66978	0.76547	0.85523
Jan-Feb Avg Temp (°C)	DFN	-7.76		-0.21800	-0.25891	-0.42134	-0.39183	-0.47549
Apr Mean Temp (°C)	DFN	6.60			0.24151	0.19529	0.28549	0.25310
May Prec (mm)	DFN	46.61				0.07030	0.06518	0.09128
May Prec (mm)	SDFN	46.61				-0.00242	-0.00167	-0.00183
Jun Prec - P.E.T. (mm)	DFN	-62.40					0.01118	0.01017
Jun Prec - P.E.T. (mm)	SDFN	-62.40					0.00059	0.00074
Jul Prec - P.E.T. (mm)	DFN	-77.54						-0.02477
R Squared			0.67730	0.70732	0.72231	0.83343	0.87270	0.88660
Standard Error (Q/Ha)			2.31145	2.24490	2.23174	1.80531	1.65525	1.60285
Standard Variance (Q/Ha)			5.34280	5.03958	4.98066	3.25915	2.73985	2.56914

Standard Deviation of Yields = 3.99291 Q/Ha

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

Yields and Climatic Data are Pooled Over Crop Regions 11 and 12
Yields Based on 1958-1971
Meteorological Normals Based on 1958-1971

CENTRAL DISTRICT SPRING WHEAT MODEL

Region

Central District - Crop Region 13

Latitude = $56^{o}N$

Variable	Deviation	Normal	Trend	April	June	August
Overall Constant		1.00	4.40233	5.19195	5.78767	5.53506
Linear Trend (1958-1973)		16.00	0.74424	0.72646	0.68813	0.79917
Apr Mean Temp (^{o}C)	DFN	5.31		-0.04278	0.10158	0.02698
Apr Mean Temp (^{o}C)	SDFN	5.31		-0.18358	-0.13446	-0.13102
Jun Prec (mm)	DFN	63.06			0.03033	0.02720
Jun Prec (mm)	SDFN	63.06			-0.00075	-0.00079
Aug Prec (mm)	DFN	63.13				0.04753
Aug Prec (mm)	SDFN	63.13				-0.00180
R Squared			0.74121	0.78510	0.81250	0.88586
Standard Error (Q/Ha)			2.16720	2.13312	2.18268	1.90394
Standard Variance (Q/Ha)			4.69674	4.55020	4.76409	3.62500

Standard Deviation of Yields = 4.11566 Q/Ha

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

Yields Based on 1958-1973
Meteorological Normals Based on 1958-1973

VOLGA-VYATSK SPRING WHEAT MODEL

Region

Volga-Vyatsk - Crop Region 14

P.E.T. A = .914
P.E.T. I = 25.737

May Daylength = 1.3517
June Daylength = 1.4448

Latitude = 56°N

Variable	Deviation	Normal	Trend	April	May	June
Overall Constant		1.00	4.80093	2.66753	3.67734	4.05194
Linear Trend (1958-1973)		16.00	0.61530	0.86628	0.82821	0.80001
Sep-Apr Prec (mm)	DFN	317.44		-0.02538	-0.02706	-0.02086
May Prec - P.E.T. (mm)	DFN	-39.41			0.02670	0.02393
May Prec - P.E.T. (mm)	SDFN	-39.41			-0.00119	-0.00125
Jun Prec - P.E.T. (mm)	DFN	-55.99				0.02452
Jun Prec - P.E.T. (mm)	SDFN	-55.99				-0.00013
R Squared			0.63230	0.70384	0.79482	0.81666
Standard Error (Q/Ha)			2.31232	2.15357	1.94864	2.03646
Standard Variance (Q/Ha)			5.34684	4.63785	3.79718	4.14717

Standard Deviation of Yields = 3.68399 Q/Ha

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

Yields Based on 1958-1973
Meteorological Normals Based on 1958-1973

Region

Upper Volga - Crop Region 15

P.E.T. A = .965 July Daylength = 1.3573 Latitude = 54°N
P.E.T. I = 29.088

Variable	Deviation	Normal	Trend	April	July
Overall Constant		1.00	7.31689	5.37479	6.41439
Linear Trend (1958-1971)		14.00	0.67783	0.93677	0.73847
Sep-Apr Prec (mm)	DFN	283.50		-0.02527	-0.02242
Jul Prec - P.E.T. (mm)	DFN	-79.23			0.05480
Jul Prec - P.E.T. (mm)	SDFN	-79.23			0.00097
R Squared			0.70224	0.82836	0.91394
Standard Error (Q/Ha)			1.92183	1.52398	1.19300
Standard Variance (Q/Ha)			3.69342	2.32253	1.42324

Standard Deviation of Yields = 3.38375 Q/Ha

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

Yields Based on 1958-1971
Meteorological Normals Based on 1958-1971

MIDDLE VOLGA SPRING WHEAT MODEL

Region

Middle Volga - Crop Region 16

P.E.T. A = 1.058 | June Daylength = 1.3748 | Latitude = 52°N
P.E.T. I = 35.238 | July Daylength = 1.3296

Variable	Deviation	Normal	Constant	April	June	July
Overall Constant		1.00	9.82458	9.82458	9.82458	9.82458
Sep-Apr Prec (mm)	DFN	269.93		0.02395	0.02296	0.02006
Jun Prec - P.E.T. (mm)	DFN	-76.04			0.05673	0.05150
Jul Prec - P.E.T. (mm)	DFN	-93.44				0.02358
R Squared			0.00000	0.42909	0.62026	0.68602
Standard Error (Q/Ha)			2.41340	1.89799	1.61676	1.54188
Standard Variance (Q/Ha)			5.82449	3.60236	2.61392	2.37740

Standard Deviation of Yields = 2.41340 Q/Ha

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

Yields Based on 1958-1971
Meteorological Normals Based on 1958-1971

NORTHWEST URALS SPRING WHEAT MODEL

Region

Northwest Urals - Crop Region 18

P.E.T. A = .874
P.E.T. I = 23.120

April Daylength = 1.882
May Daylength = 1.3834
June Daylength = 1.4885

Latitude = 58°N

Variable	Deviation	Normal	Trend	April	May	June
Overall Constant		1.00	6.24429	8.18627	7.78111	8.13741
Linear Trend (1958-1973)		16.00	0.27531	0.04685	0.09451	0.09651
Apr Prec - P.E.T. (mm)	DFN	8.39		0.09554	0.09193	0.06438
Apr Mean Temp (°C)	DFN	2.87		0.93806	0.78612	0.53556
May Prec - P.E.T. (mm)	DFN	-44.75			-0.01376	-0.02616
Jun Prec - P.E.T. (mm)	DFN	-61.52				0.04317
Jun Prec - P.E.T. (mm)	SDFN	-61.52				-0.00040
R Squared			0.31130	0.56019	0.57666	0.76002
Standard Error (Q/Ha)			2.01803	1.74188	1.78494	1.48573
Standard Variance (Q/Ha)			4.07246	3.03414	3.18602	2.20739

Standard Deviation of Yields = 2.41340 Q/Ha

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

Yields Based on 1958-1973
Meteorological Normals Based on 1958-1973

May 1977

SOUTHERN URALS-WESTERN KAZAKHSTAN SPRING WHEAT COVARIANCE MODEL

Region

Southern Urals - Crop Region 19
Western Kazakhstan - Crop Region 21

P.E.T. A = 1.076 May Daylength = 1.4010 Latitude = 59°N
P.E.T I = 36.473 June Daylength = 1.5135

Crop Region 21 Constant = 1 if Data from Crop Region 21; Otherwise 0

Variable	Deviation	Normal	Constant	April	May	June	July
Overall Constant		1.00	11.14404	10.50547	10.65578	10.75772	10.13858
Crop Region 21 Constant		1.00	-4.35112	-2.90132	-3.20907	-2.62653	-1.83449
Nov-Apr Prec (mm)	DFN	141.94		0.04463	0.04705	0.03239	0.03203
Nov-Apr Prec (mm)	SDFN	141.94		0.00008	0.00006	-0.00012	-0.00003
May Prec - P.E.T. (mm)	DFN	-73.82			-0.01246	-0.02435	-0.02567
Jun Prec - P.E.T. (mm)	DFN	-105.97				0.05190	0.02902
Jul Mean Temp (°C)	DFN	21.73					-0.66473
R Squared			0.30510	0.56484	0.56877	0.63295	0.71302
Standard Error (Q/Ha)			3.28612	2.72145	2.77604	2.62769	2.38715
Standard Variance (Q/Ha)			10.79856	7.40627	7.70642	6.90474	5.69849

Standard Deviation of Yields = 3.85906 Q/Ha

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

Yields and Climatic Data are Pooled Over Crop Regions 19 and 21
Yields Based on 1958-1973, 1962-1964, 1969-1970, and 1972-1973, Missing for Western Kazakhstan
Meteorological Normals Based on 1958-1973

NORTHEASTERN URALS SPRING WHEAT MODEL

Region

Northeastern Urals - Crop Region 20

P.E.T. A = .898 June Daylength = 1.4448 Latitude = 56^{o}N
P.E.T. I = 24.720

Variable	Deviation	Normal	Trend	April	June	August
Overall Constant		1.00	9.37018	9.97322	12.72468	12.68680
Linear Trend (1958-1973)		16.00	0.42498	0.35404	0.03033	0.03479
Apr Prec (mm)	DFN	23.56		0.08081	0.00936	0.01663
Jun Prec - P.E.T. (mm)	DFN	-62.88			0.09048	0.10930
Aug Prec (mm)	DFN	55.88				-0.05692
R Squared			0.31550	0.38293	0.66771	0.76703
Standard Error (Q/Ha)			3.08486	3.03954	2.32156	2.03031
Standard Variance (Q/Ha)			9.51633	9.23880	5.38965	4.12215

Standard Deviation of Yields = 3.60219 Q/Ha

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

Yields Based on 1958-1973
Meteorological Normals Based on 1958-1973

NORTHEAST KAZAKH SPRING WHEAT COVARIANCE MODEL

Region

Kunstanay - Crop Region 22
Tselinograd - Crop Region 23
Northern Kazakhstan - Crop Region 24
Pavlodar - Crop Region 25

P.E.T. A = .987
P.E.T. I = 30.533

May Daylength = 1.3113
June Daylength = 1.3906
July Daylength = 1.3431

Latitude = 53°N

Crop Region 24 Constant = 1 if Data from Crop Region 24; Otherwise 0

Variable	Deviation	Normal	Constant	April	May	June	July
Overall Constant		1.00	7.39502	7.60706	7.65250	7.93874	9.34027
Crop Region 24 Constant		1.00	2.10275	1.76968	1.69216	1.43237	0.80349
Apr Mean Temp (°C)	DFN	4.06		-0.45418	-0.12129	-0.23457	-0.50309
May Prec - P.E.T. (mm)	DFN	-55.55			0.04311	0.02434	0.02165
Jun Prec - P.E.T. (mm)	DFN	-94.26				0.07773	0.07456
Jul Prec - P.E.T. (mm)	SDFN	-85.95					-0.00127
Jul Mean Temp (°C)	DFN	20.31					-0.51645
R Squared			0.09543	0.20096	0.32184	0.52166	0.72607
Standard Error (Q/Ha)			2.88452	2.75181	2.57445	2.19674	1.71874
Standard Variance (Q/Ha)			8.32046	7.57247	6.62778	4.82567	2.95407

Standard Deviation of Yields = 2.98922 Q/Ha

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

Yields and Climatic Data are Pooled Over Crop Regions 22, 23, 24, and 25
Yields Based on 1958-1961, 1965-1968, 1971
Meteorological Normals Based on 1958-1971

SIBERIA-ALTAI SPRING WHEAT COVARIANCE MODEL

Region

West Siberia - Crop Region 26
Altai Krai - Crop Region 27

P.E.T. A = .922
P.E.T. I = 26.232

May Daylength = 1.3517
June Daylength = 1.4448
July Daylength = 1.3887

Latitude = 56°N

Crop Region 26 Constant = 1 if Data from Crop Region 26; Otherwise 0

Variable	Deviation	Normal	Constant	March	April	May	June	July	August
Overall Constant		1.00	10.36206	10.14462	10.72857	12.46659	11.69695	13.12888	13.23614
Crop Region 26 Constant		1.00	-0.50450	-0.06966	-0.14280	-1.65014	-1.66298	-2.35021	-2.17003
Sep-Mar Prec (mm)	DFN	193.33		0.03362	-0.00437	-0.00827	-0.02072	-0.01831	-0.01377
Apr Prec (mm)	DFN	25.97			0.22124	0.14560	0.12189	0.08049	0.10557
Apr Prec (mm)	SDFN	25.97			-0.00446	-0.00514	-0.00382	-0.00480	-0.00526
May Prec - P.E.T. (mm)	DFN	-49.88				0.05790	0.04042	0.04680	0.05530
May Prec - P.E.T. (mm)	SDFN	-49.88				-0.00106	-0.00034	-0.00049	-0.00036
Jun Prec - P.E.T. (mm)	DFN	-74.45					0.06239	0.07056	0.07219
Jul Prec - P.E.T. (mm)	SDFN	-78.85						-0.00064	-0.00084
Aug Prec (mm)	DFN	53.77							-0.05937
R Squared			0.00447	0.10830	0.42824	0.56393	0.68148	0.72495	0.80402
Standard Error (Q/Ha)			3.89871	3.75750	3.12686	2.84698	2.48789	2.36630	2.04675
Standard Variance (Q/Ha)			15.19996	14.11882	9.77723	8.10532	6.18958	5.59937	4.18919

Standard Deviation of Yields = 3.83949 (Q/Ha)

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

Yields and Climatic Data are Pooled Over Crop Regions 26 and 27
Yields Based on 1958-1972
Meteorological Normals Based on 1958-1972

SOUTH KAZAKHSTAN SPRING WHEAT MODEL

Region

South Kazakhstan - Crop Region 29

P.E.T. A = 1.015
P.E.T. I = 32.393

June Daylength = 1.3460
July Daylength = 1.3049

Latitude = 50°N

Variable	Deviation	Normal	Constant	April	May	June	July	August
Overall Constant		1.00	8.20883	8.22386	8.35113	8.09219	8.07708	7.88205
Sep-Apr Prec (mm)	DFN	170.12		0.03913	0.04524	0.06256	0.06507	0.05346
May Temp (°C)	DFN	13.19			-0.62806	-0.21515	-0.17299	-0.18741
Jun Prec - P.E.T. (mm)	DFN	-94.93				0.10224	0.10043	0.09599
Jul Prec - P.E.T. (mm)	DFN	-97.29					0.00757	0.00658
Aug Prec (mm)	DFN	32.61						-0.05057
R Squared			0.00000	0.21318	0.55796	0.78559	0.79261	0.81376
Standard Error (Q/Ha)			2.79059	2.56877	2.00400	1.45777	1.50366	1.50203
Standard Variance (Q/Ha)			7.78739	6.59859	4.01602	2.12510	2.26098	2.25608

Standard Deviation of Yields = 2.79059 Q/Ha

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

Yields Based on 1958-1968 and 1971-1974
Meteorological Normals Based on 1957-1974

CENTRAL ASIA SPRING WHEAT MODEL

Region

Central Asia - Crop Region 30

P.E.T. A = 1.421	April Daylength = 1.0977	Latitude = 40°N
P.E.T. I = 59.091	May Daylength = 1.1921	
	June Daylength = 1.2373	

Variable	Deviation	Normal	Constant	April	May	June	July
Overall Constant		1.00	5.85231	6.33719	6.78623	7.44896	7.43362
Apr Prec - P.E.T. (mm)	DFN	24.17		0.01504	0.00626	0.00780	0.00821
Apr Prec - P.E.T. (mm)	SDFN	24.17		-0.00040	-0.00040	-0.00050	-0.00049
May Prec - P.E.T. (mm)	DFN	-52.30			0.01943	0.01957	0.01872
May Prec - P.E.T. (mm)	SDFN	-52.30			-0.00044	-0.00061	-0.00060
Jun Prec - P.E.T. (mm)	DFN	-121.27				-0.00686	-0.00755
Jun Prec - P.E.T. (mm)	SDFN	-121.27				-0.00179	-0.00178
Jul Temp (°C)	DFN	25.94					-0.06632
R Squared			0.00000	0.28803	0.62768	0.83811	0.84042
Standard Error (Q/Ha)			1.17600	1.06080	0.82858	0.59852	0.62638
Standard Variance (Q/Ha)			1.38298	1.12530	0.68654	0.35823	0.39236

Standard Deviation of Yields = 1.17600 Q/Ha

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

Yields Based on 1958-1974
Meteorological Normals Based on 1958-1974

EASTERN SIBERIA SPRING WHEAT MODEL

Region

Eastern Siberia - Crop Region 31

P.E.T. A = .906
P.E.T. I = 25.181

June Daylength = 1.3906

Latitude = 53°N

Variable	Deviation	Normal	Trend	May	June	July	August
Overall Constant		1.00	9.21112	9.32541	10.17852	10.23747	9.68920
Linear Trend (1958-1972)		15.00	0.26451	0.25022	0.14358	0.13621	0.20475
Mar-May Prec (mm)	DFN	68.73		0.01594	0.02380	0.02315	0.02714
Jun Prec - P.E.T. (mm)	DFN	-68.08			0.07714	0.05760	0.06060
Jul Temp (°C)	DFN	19.12				-0.44442	-0.12261
Aug Prec (mm)	DFN	60.80					-0.03368
R Squared			0.27949	0.30623	0.71120	0.76052	0.85004
Standard Error (Q/Ha)			1.97101	2.01307	1.35656	1.29562	1.08070
Standard Variance (Q/Ha)			3.88489	4.05244	1.84026	1.67863	1.16790

Standard Deviation of Yields = 2.23757 Q/Ha

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

Yields Based on 1958-1972
Meteorological Normal Based on 1958-1972

FAR EAST SPRING WHEAT MODEL

Region

Far East - Crop Region 32

P.E.T. A = .997
P.E.T. I = 31.201

June Daylength = 1.3460
July Daylength = 1.3049

Latitude = 50°N

Variable	Deviation	Normal	Trend	May	June	July	September
Overall Constant		1.00	5.47145	5.99671	6.47163	6.60890	6.75554
Linear Trend (1958-1972)		15.00	0.37941	0.29597	0.33527	0.36973	0.42602
May Temp ($^{\circ}$C)	DFN	11.48		0.76039	0.48272	0.08222	-0.85102
Jun Prec - P.E.T. (mm)	DFN	-31.37			0.01584	0.01990	0.02472
Jun Prec - P.E.T. (mm)	SDFN	-31.37			-0.00025	-0.00037	-0.00052
Jul Prec - P.E.T. (mm)	DFN	-11.88				0.00946	0.02187
Sep Prec (mm)	DFN	76.07					-0.02711
R Squared			0.53412	0.62298	0.77856	0.79712	0.86153
Standard Error (Q/Ha)			1.65844	1.55826	1.32027	1.34037	1.18379
Standard Variance (Q/Ha)			2.75042	2.42818	1.74312	1.79658	1.40136

Standard Deviation of Yields = 2.33443 Q/Ha

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

Yields Based on 1958-1968 and 1970-1972
Meteorological Normals Based on 1958-1972 for One Station - Blagoveschesk

NORTHWEST SPRING WHEAT MODEL

Region

Northwest - Crop Region 33

P.E.T. A = .897 June Daylength = 1.4885 Latitude = 58°N
P.E.T. I = 24.646

Variable	Deviation	Normal	Trend	April	June	July
Overall Constant		1.00	4.41524	4.48170	5.13108	5.18313
Linear Trend (1958-1972)		15.00	0.46762	0.45829	0.45822	0.45239
Apr Prec (mm)	DFN	34.80		0.00461	0.01411	0.01182
Jun Prec - P.E.T. (mm)	DFN	-66.10			0.01664	0.01306
Jun Prec - P.E.T. (mm)	SDFN	-66.10			-0.00059	-0.00059
Jul Temp (°C)	DFN	17.57				-0.16707
R Squared			0.64011	0.64068	0.69258	0.70450
Standard Error (Q/Ha)			1.57275	1.64139	1.67847	1.74541
Standard Variance (Q/Ha)			2.47355	2.69414	2.81725	3.04646

Standard Deviation of Yields = 2.51880 Q/Ha

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

Yields Based on 1958-1970 and 1972
Meteorological Normals Based on 1958-1972