LARGE AREA CROP INVENTORY EXPERIMENT (LACIE)

NASA NOAA USDA

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

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YIELD MODELS FOR THE USSR

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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.
Figure 2. March of production and spring and winter wheat sown area in the U.S.S.R. from 1950-1973 (source: CIA, 1974).
Figure 3. Spring wheat yield in the Russian Soviet Federated Socialist Republic (RSFSR), 1949-1972 (data: Manellya, et al., 1972).
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°C (90°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 \(-40^\circ C\) \((-40^\circ F\) 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 \(-32^\circ C\) \((-25^\circ F\) (Martin and Leonard, 1949). Martin and Leonard also indicate that spring wheat can withstand temperatures as low as \(-9^\circ C\) \((15^\circ F)\). 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 Alpatov 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).
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:

\[ y_{ij} = \alpha_j + \beta T_i + \sum_{k=1}^{n} \gamma_{ik} w_{ijk} + \epsilon_{ij} \]

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 $i$th year and $j$th subregion

$\alpha_j =$ constant for the $j$th subregion

$\beta =$ coefficient for trend, $T$

$T_i =$ trend for $i$th year (1958=1, 1959=2, \ldots, 1973=16)

$Y_{jk} =$ coefficient for $k$th 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 $k$th weather variable is not the same function for each model.

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

$\varepsilon_{ij} =$ unexplained variation of the $i$th year and $j$th 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 $\beta$ 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.

\((T)_m = \text{monthly mean temperature (°C) for month m}\)

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, \(\bar{P}_m\), 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 \(T_m - \bar{T}_m\) where \(T_m\) is the observed temperature and \(\bar{T}_m\) 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.
REFERENCES


### APPENDIX

#### U.S.S.R. WINTER WHEAT MODELS

<table>
<thead>
<tr>
<th>Region</th>
<th>Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltics-Belorussia</td>
<td>1. Baltics, 2. Belorussia</td>
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<tr>
<td>Moldavia</td>
<td>8. Moldavia</td>
</tr>
<tr>
<td>Caucasus-Volga</td>
<td>10. Northeast Caucasus, 17. Lower Volga</td>
</tr>
<tr>
<td>Black Soil Zone</td>
<td>11. West Black Soil Zone, 12. East Black Soil Zone</td>
</tr>
<tr>
<td>Central District</td>
<td>13. Central Region</td>
</tr>
<tr>
<td>Volga-Vyatsk</td>
<td>14. Volga-Vyatsk</td>
</tr>
<tr>
<td>Upper Volga</td>
<td>15. Upper Volga</td>
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<tr>
<td>Middle Volga</td>
<td>16. Middle Volga</td>
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<tr>
<td>Northwest Urals</td>
<td>18. Northwest Urals</td>
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<tr>
<td>Transcaucasus</td>
<td>28. Transcaucasus</td>
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<td>South Kazakhstan</td>
<td>29. South Kazakhstan</td>
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<td>Central Asia</td>
<td>30. Central Asia</td>
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<tr>
<td>Northwest</td>
<td>33. Northwest</td>
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</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
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<tbody>
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<td>0.85246</td>
<td>0.86025</td>
<td>0.86928</td>
<td>0.87596</td>
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<td>2.35275</td>
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<td>5.80150</td>
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<td>5.53542</td>
<td>5.46273</td>
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</table>

**Standard Deviation of Yields = 5.95955 Q/Ha**

DFN = Departure from Normal  
Yields and Climatic Data are Pooled Over Crop Regions 1 and 2  
SDFN = Squared Departure from Normal  
Yields Based on 1958-1973  
Yields Measured in Quintals per Hectare  
Meteorological Normals Based on 1958-1973

May 1977
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 -4.55768 -5.32192 -6.7375
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 0.83038 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 1.1158
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 -0.0063
Jun Prec – P.E.T. (mm) DFN -52.52 0.03712
Jun Prec – P.E.T. (mm) SDFN -52.52

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

May 1977
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
P.E.T. I = 45.130

April Daylength = 1.1251
Latitude = 47°N

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

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<td>2.65198</td>
<td>2.58917</td>
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<tr>
<td>Standard Variance (Q/Ha)</td>
<td></td>
<td>16.78789</td>
<td>7.61124</td>
<td>7.03298</td>
<td>6.70382</td>
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Standard Deviation of Yields = 5.40947 Q/ha

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields and Climatic data are Pooled Over Crop Regions 6, 7, and 9
Yields Based on 1958-1972
Meteorological Normals Based on 1958-1972

May 1977
**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

<table>
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<th>Trend</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>June</th>
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<td>Linear Trend (1958-1973)</td>
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<td>1.45563</td>
<td>1.56671</td>
<td>1.61532</td>
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<td>Jan-Feb Avg Temp (°C)</td>
<td>DFN</td>
<td>-2.26</td>
<td>1.25431</td>
<td>1.20052</td>
<td>1.25488</td>
<td>0.84182</td>
<td>0.84113</td>
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<td>Mar Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>20.81</td>
<td>-0.06288</td>
<td>-0.07146</td>
<td>-0.14263</td>
<td>-0.10165</td>
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<td>Apr Prec - P.E.T. (mm)</td>
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<td>0.06089</td>
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<td>Jun Temp (°C)</td>
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<td>-1.39325</td>
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<td>Jul Prec (mm)</td>
<td>DFN</td>
<td>60.63</td>
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</table>

**R Squared**  
0.50283  
5.88632  
34.64873

**Standard Error (Q/Ha)**  
0.63447  
5.23781  
27.43462

**Standard Variance (Q/Ha)**  
0.66253  
5.23821  
27.43881

**Standard Deviation of Yields = 8.06514 Q/Ha**

**DFN** = Departure from Normal  
**SDFN** = Squared Departure from Normal  
**Yields** Based on 1958-1973  
**Meteorological Normals Based on 1958-1973**  
**Yields Measured in Quintals per Hectare**

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

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
<th>March</th>
<th>April</th>
<th>May</th>
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</thead>
<tbody>
<tr>
<td>Overall Constant</td>
<td>1.00</td>
<td>14.3594</td>
<td>16.6399</td>
<td>16.7722</td>
<td>18.1607</td>
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<tr>
<td>Region 10 Constant</td>
<td>1.00</td>
<td>1.3557</td>
<td>-2.4753</td>
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<tr>
<td>Sep-Mar Prec (mm)</td>
<td>DFN</td>
<td>233.75</td>
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<tr>
<td>Nov-Mar Temp (°C)</td>
<td>DFN</td>
<td>-2.98</td>
<td>1.1279</td>
<td>0.9262</td>
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<td>Nov-Mar Temp (°C)</td>
<td>SDFN</td>
<td>-2.98</td>
<td>-0.0609</td>
<td>-0.0984</td>
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<td>Apr Temp (°C)</td>
<td>DFN</td>
<td>9.17</td>
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<td>0.5050</td>
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<td>Apr Temp (°C)</td>
<td>SDFN</td>
<td>9.17</td>
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<tr>
<td>May Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-57.03</td>
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<td>May Prec - P.E.T. (mm)</td>
<td>SDFN</td>
<td>-57.03</td>
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<td>-0.0014</td>
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R Squared: 0.02583
Standard Error (Q/Ha): 4.32000
Standard Variance (Q/Ha): 18.66241

Standard Deviation of Yields = 4.29508 Q/Ha

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields and Climatic Data are Pooled Over Crop Regions 10 and 17
Yields Based on 1958-1971
Meteorological Normals Based on 1958-1971

May 1977
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
P.E.T. I = 32.810

May Daylength = 1.2880
Latitude = 51°N

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

<table>
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<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
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<tbody>
<tr>
<td>Overall Constant</td>
<td>1.00</td>
<td>12.63277</td>
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<td>10.39611</td>
<td>11.10661</td>
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<tr>
<td>Region 12 Constant</td>
<td>1.00</td>
<td>0.65617</td>
<td>1.80616</td>
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<tr>
<td>Linear Trend (1958-1971)</td>
<td>14.00</td>
<td>0.47866</td>
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<td>0.70808</td>
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<tr>
<td>Jan-Feb Temp (°C)</td>
<td>DFN</td>
<td>-7.76</td>
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<tr>
<td>Mar Temp (°C)</td>
<td>DFN</td>
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<td>Apr Prec (mm)</td>
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<td>0.03232</td>
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<td>Apr Prec (mm)</td>
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<td>-0.16711</td>
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<td>May Prec - P.E.T. (mm)</td>
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<td>-43.95</td>
<td>0.01999</td>
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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 and Climatic Data are Pooled Over Crop Regions 11 and 12
Yields Based on 1958-1971
Meteorological Normals Based on 1958-1971

May 1977
### Central District Winter Wheat Model

#### Region

**Central District - Crop Region 13**

**P.E.T. A** = 0.937  
**P.E.T. I** = 27.226

- **May Daylength** = 1.3517
- **Latitude** = 56°N

<table>
<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
<th>March</th>
<th>April</th>
<th>May</th>
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<tbody>
<tr>
<td>Overall Constant</td>
<td>1.00</td>
<td>6.98680</td>
<td>6.61694</td>
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<td>Linear Trend (1958-1973)</td>
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<td>Dec-Mar Temp (°C)</td>
<td>DFN</td>
<td>0.35037</td>
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<td>Apr Temp (°C)</td>
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<td>May Prec - P.E.T. (mm)</td>
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<td>-36.04</td>
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</table>

- **R Squared** = 0.71230  
- **Standard Error (Q/ha)** = 2.04810  
- **Standard Variance (Q/ha)** = 4.19473

**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

May 1977
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

<table>
<thead>
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<th>Trend</th>
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<th>May</th>
<th>June</th>
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<tbody>
<tr>
<td>Overall Constant</td>
<td>1.00</td>
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<tr>
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<td>0.06491</td>
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<td>-0.00118</td>
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</table>

R Squared                     | 0.72518   | 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 Based on 1958-1973
Meteorological Normals Based on 1958-1973
Yields Measured in Quintals per Hectare

May 1977
### UPPER VOLGA WINTER WHEAT MODEL

**Region**

Upper Volga - Crop Region 15

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

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<thead>
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<td>Jun Prec - P.E.T. (mm)</td>
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</table>

**Standard Deviation of Yields = 3.73550 Q/Ha**

DFN = Departure from Normal  
SDFN = Squared Departure from Normal  
Yields Based on 1958-1971

May 1977
MIDDLE VOLGA WINTER WHEAT MODEL

Region
Middle Volga - Crop Region 16

P.E.T. A = 1.058
P.E.T. I = 35.238

May Daylength = 1.2994
Latitude = 52°N

<table>
<thead>
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<th>Variable</th>
<th>Deviation</th>
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<th>May</th>
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</thead>
<tbody>
<tr>
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<td>DFN</td>
<td>6.23</td>
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<td>Apr Temp (°C)</td>
<td>SDFN</td>
<td>6.23</td>
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<td>May Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-59.29</td>
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</table>

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 Based on 1958-1971
Meteorological Normals Based on 1958-1971
Yields Measured in Quintals per Hectare

May 1977
## NORTHWEST URALS WINTER WHEAT MODEL

### Region

Northwest Urals - Crop Region 18

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

Latitude = 58°N

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
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<tbody>
<tr>
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<td>11.64</td>
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<td>DFN</td>
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<td>0.21</td>
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<td>-0.20</td>
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<td>-60.47</td>
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<td></td>
<td></td>
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</table>

R Squared

| Standard Error (Q/Ha)      | 0.29633   | 0.50815 | 0.69021 | 0.78888 | 0.82644 |
| Standard Variance (Q/Ha)   | 1.97784   | 1.75387 | 1.48802 | 1.45348 | 1.47342 |

Standard Deviation of Yields = 2.1327 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

May 1977
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° N

<table>
<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
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<td>7.13531</td>
<td>7.48573</td>
<td>7.57169</td>
<td>7.64755</td>
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<tr>
<td>Linear Trend (1958-1974)</td>
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<td>Apr Prec (mm)</td>
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<td>-0.02818</td>
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<td>Apt Prec (mm)</td>
<td>SDFN</td>
<td>26.82</td>
<td>-0.00340</td>
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<td>-0.00208</td>
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<tr>
<td>May Temp (°C)</td>
<td>DFN</td>
<td>18.19</td>
<td>-0.31632</td>
<td>-0.05342</td>
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<tr>
<td>Jun Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-106.97</td>
<td>0.02749</td>
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<td>Jun Prec - P.E.T. (mm)</td>
<td>SDFN</td>
<td>-106.97</td>
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<tr>
<td>R Squared</td>
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<td>0.76412</td>
<td>0.80493</td>
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<tr>
<td>Standard Error (Q/Ha)</td>
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<td>1.38844</td>
<td>1.35629</td>
<td>1.35774</td>
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<td>Standard Variance (Q/Ha)</td>
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<td></td>
<td>1.92776</td>
<td>1.83951</td>
<td>1.84345</td>
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Standard Deviation of Yields = 2.76801 Q/Ha

DEN = Departure from Normal
SDEN = Squared Departure from Normal
Yields Based on 1958-1974
Meteorological Normals Based on 1958-1974
Yields Measured in Quintals per Hectare

May 1977
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

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<thead>
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<th>Constant</th>
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<th>April</th>
<th>May</th>
<th>June</th>
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<tbody>
<tr>
<td>Overall Constant</td>
<td>1.00</td>
<td>10.45508</td>
<td>10.45508</td>
<td>10.70239</td>
<td>11.99482</td>
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<td>Dec-Mar Temp (°C)</td>
<td>DFN</td>
<td>0.44</td>
<td>0.20381</td>
<td>0.16862</td>
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<td>0.15290</td>
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<td>Apr Temp (°C)</td>
<td>DFN</td>
<td>12.86</td>
<td>-0.62323</td>
<td>-0.16378</td>
<td>-0.21217</td>
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<tr>
<td>Apr Temp (°C)</td>
<td>SDFN</td>
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<td>-0.08628</td>
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<td>May Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-44.62</td>
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<td>0.06023</td>
<td>0.05791</td>
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<tr>
<td>May Prec - P.E.T. (mm)</td>
<td>SDFN</td>
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<td></td>
<td>-0.00121</td>
<td>-0.00115</td>
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<td>Jun Temp (°C)</td>
<td>DFN</td>
<td>23.21</td>
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</table>

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 Deviation of Yields = 3.00576 Q/Ha

DFN = Departure from Normal
SDFN = Squared Departure from Normal
Yields Based on 1958-1974
Yields Measured in Quintals per Hectare

May 1977


**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

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<th>Trend</th>
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<th>April</th>
<th>May</th>
<th>June</th>
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<td>Overall Constant</td>
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<td>5.20955</td>
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<td>5.53685</td>
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<td>Linear Trend (1958-1974)</td>
<td>17.00</td>
<td>0.29145</td>
<td>0.34190</td>
<td>0.33583</td>
<td>0.30553</td>
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<td>Nov-Mar Prec (mm)</td>
<td>DFN</td>
<td>241.71</td>
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<tr>
<td>Apr Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>24.17</td>
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<td>May Prec - P.E.T. (mm)</td>
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<td>-52.30</td>
<td>0.01897</td>
<td>0.01828</td>
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<td>Jun Temp (°C)</td>
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<td>24.15</td>
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<td></td>
<td>-0.15456</td>
<td></td>
</tr>
</tbody>
</table>

R Squared  
Standard Error (Q/ha)  
Standard Variance (Q/ha)

| 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

May 1977
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°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

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

May 1977
### 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°N

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<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Constant</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
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</thead>
<tbody>
<tr>
<td>Overall Constant</td>
<td>DFN</td>
<td>1.00</td>
<td>9.33175</td>
<td>9.26464</td>
<td>8.97282</td>
<td>8.94580</td>
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<td>Sep-Apr Prec (mm)</td>
<td>DFN</td>
<td>261.57</td>
<td>0.02714</td>
<td>0.02454</td>
<td>0.02924</td>
<td>0.03112</td>
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<td>Sep-Apr Prec (mm)</td>
<td>SDFN</td>
<td>261.57</td>
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<td>0.00010</td>
<td>0.00014</td>
<td>0.00018</td>
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<tr>
<td>Apr Mean Temp (°C)</td>
<td>DFN</td>
<td>9.36</td>
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<td>0.41367</td>
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<tr>
<td>May Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-57.92</td>
<td>0.07652</td>
<td>0.08253</td>
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<td>May Prec - P.E.T. (mm)</td>
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<td>-0.00034</td>
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<td>Jun Prec (mm)</td>
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<td>-0.00874</td>
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<td>Jul Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-114.28</td>
<td>-0.01664</td>
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<tr>
<td>Jul Prec - P.E.T. (mm)</td>
<td>SDFN</td>
<td>-114.28</td>
<td>-0.00089</td>
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</table>

- **R Squared** = 0.00000  
- **Standard Error (Q/ha)** = 3.38297  
- **Standard Variance (Q/ha)** = 11.44451

**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

May 1977
### 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.
- P.E.T. A = 1.021
- P.E.T. I = 32.810

#### June Daylength = 1.3600

#### July Daylength = 1.3170

#### Latitude = 51°N

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<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
<th>February</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
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<td>Overall Constant</td>
<td>1.00</td>
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<td>7.54990</td>
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<td>Linear Trend (1958-1971)</td>
<td>14.00</td>
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<td>Jan-Feb Avg Temp (°C)</td>
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<td>Apr Mean Temp (°C)</td>
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<td>6.60</td>
<td>0.24151</td>
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<td>May Prec (mm)</td>
<td>DFN</td>
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<td>May Prec (mm)</td>
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<td>46.61</td>
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<td>Jun Prec - P.E.T. (mm)</td>
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<td>Jun Prec - P.E.T. (mm)</td>
<td>SDFN</td>
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<td>-0.02477</td>
<td></td>
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<td></td>
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</tbody>
</table>

**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 and Climatic Data are Pooled Over Crop Regions 11 and 12
Yields Based on 1958-1971
Yields Measured in Quintals per Hectare
Meteorological Normals Based on 1958-1971

May 1977
### Central District Spring Wheat Model

#### Region

Central District - Crop Region 13

Latitude = 56°N

<table>
<thead>
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<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
<th>April</th>
<th>June</th>
<th>August</th>
</tr>
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<tbody>
<tr>
<td>Overall Constant</td>
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<td>4.40233</td>
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</tr>
<tr>
<td>Linear Trend (1958-1973)</td>
<td>16.00</td>
<td>0.74424</td>
<td>0.72646</td>
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<td>Apr Mean Temp (°C)</td>
<td>DFN</td>
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<td>SDFN</td>
<td>5.31</td>
<td>-0.18358</td>
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<tr>
<td>Jun Prec (mm)</td>
<td>DFN</td>
<td>63.06</td>
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<td>0.02720</td>
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<td>Jun Prec (mm)</td>
<td>SDFN</td>
<td>63.06</td>
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<td>Aug Prec (mm)</td>
<td>DFN</td>
<td>63.13</td>
<td>0.04753</td>
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<td>Aug Prec (mm)</td>
<td>SDFN</td>
<td>63.13</td>
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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 Based on 1958-1973
Meteorological Normals Based on 1958-1973
Yields Measured in Quintals per Hectare

May 1977
### Volga-Vyatka Spring Wheat Model

**Region**

Volga-Vyatka - Crop Region 14

- P.E.T. A = 0.914
- P.E.T. I = 25.737
- May Daylength = 1.3517
- June Daylength = 1.4448

<table>
<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
<th>April</th>
<th>May</th>
<th>June</th>
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<tbody>
<tr>
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<td>2.66753</td>
<td>3.67734</td>
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<tr>
<td>Linear Trend (1958-1973)</td>
<td>16.00</td>
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<td>0.86628</td>
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<tr>
<td>Sep-Apr Prec (mm) DFN</td>
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<tr>
<td>May Prec - P.E.T. (mm) DFN</td>
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<tr>
<td>May Prec - P.E.T. (mm) SDFN</td>
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<tr>
<td>Jun Prec - P.E.T. (mm) DFN</td>
<td>-55.99</td>
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</table>

R Squared

<p>| | |</p>
<table>
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<tr>
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<tr>
<td>Overall Constant</td>
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<tr>
<td>Linear Trend (1958-1973)</td>
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<td>Sep-Apr Prec (mm) DFN</td>
<td>5.34684</td>
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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

- May 1977
## Upper Volga Spring Wheat Model

**Region**

Upper Volga - Crop Region 15

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

<table>
<thead>
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<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
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<th>July</th>
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<tbody>
<tr>
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<td>7.31689</td>
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<tr>
<td>Linear Trend (1958-1971)</td>
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<td>Sep-Apr Prec (mm)</td>
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<tr>
<td>Jul Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-79.23</td>
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<td>Jul Prec - P.E.T. (mm)</td>
<td>SDFN</td>
<td>-79.23</td>
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<td>0.00097</td>
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</table>

R Squared = 0.70224  
1.92183  
3.69342  
Yields Based on 1958-1971

Standard Error (Q/Ha) = 1.92183  
1.52398  
1.19300  
Meteorological Normals Based on 1958-1971

Standard Deviation of Yields = 3.38375 Q/Ha

Yields Measured in Quintals per Hectare
## MIDDLE VOLGA SPRING WHEAT MODEL

**Region**

Middle Volga - Crop Region 16

<table>
<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Constant</th>
<th>April</th>
<th>June</th>
<th>July</th>
<th>Latitude</th>
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<tbody>
<tr>
<td>Sep-Apr Prec (mm)</td>
<td>DFN 269.93</td>
<td>0.02395</td>
<td>0.02296</td>
<td>0.02006</td>
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<td>Jun Prec - P.E.T. (mm)</td>
<td>DFN -76.04</td>
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<td>Jul Prec - P.E.T. (mm)</td>
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<tr>
<td>Standard Error (Q/Ha)</td>
<td>2.41340</td>
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<td>1.61676</td>
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<td>Standard Variance (Q/Ha)</td>
<td>5.82449</td>
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<td>2.37740</td>
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**Standard Deviation of Yields** = 2.41340 Q/Ha

- DFN = Departure from Normal
- SDFN = Squared Departure from Normal
- Yields Based on 1958-1971
- Meteorological Normals Based on 1958-1971

Yields Measured in Quintals per Hectare

May 1977
## NORTHWEST URALS SPRING WHEAT MODEL

### Region

Northwest Urals - Crop Region 18

- **P.E.T. A** = 0.874
- **P.E.T. I** = 23.120
- **April Daylength** = 1.882
- **May Daylength** = 1.3834
- **June Daylength** = 1.4885
- **Latitude** = 58°N

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<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Constant</td>
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<td>1.00</td>
<td>6.24429</td>
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<td>Linear Trend (1958-1973)</td>
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<td>16.00</td>
<td>0.27531</td>
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<td>Apr Prec - P.E.T. (mm)</td>
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<td>8.39</td>
<td>0.09554</td>
<td>0.09193</td>
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<td>Apr Mean Temp (°C)</td>
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<td>2.87</td>
<td>0.93806</td>
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<td>Jun Prec - P.E.T. (mm)</td>
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<td>-61.52</td>
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<td>Jun Prec - P.E.T. (mm)</td>
<td>SDFN</td>
<td>-61.52</td>
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<td>-0.00040</td>
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</tr>
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</table>

- **R Squared**
  - April: 0.31130
  - May: 0.56019
  - June: 0.57666

- **Standard Error (Q/Ha)**
  - April: 2.01803
  - May: 1.74188
  - June: 1.8494

- **Standard Variance (Q/Ha)**
  - April: 4.07246
  - May: 3.03414
  - June: 3.18602

- **Standard Deviation of Yields** = 2.41340 Q/Ha

DFN = Departure from Normal
Yields Based on 1958-1973

SDFN = Squared Departure from Normal
Meteorological Normals Based on 1958-1973
Yields Measured in Quintals per Hectare

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

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

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<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Constant</th>
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<th>May</th>
<th>June</th>
<th>July</th>
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<tbody>
<tr>
<td>Overall Constant</td>
<td>1.00</td>
<td>11.14404</td>
<td>10.50547</td>
<td>10.65578</td>
<td>10.75772</td>
<td>10.13858</td>
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<tr>
<td>Crop Region 21 Constant</td>
<td>1.00</td>
<td>141.94</td>
<td>-4.35112</td>
<td>-2.90132</td>
<td>-3.20907</td>
<td>-2.62653</td>
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<td>Nov-Apr Prec (mm)</td>
<td>DFN</td>
<td>141.94</td>
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<td>0.04705</td>
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<td>Jun Prec - P.E.T. (mm)</td>
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<td>0.02902</td>
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<td>Jul Mean Temp (°C)</td>
<td>DFN</td>
<td>21.73</td>
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<td>0.56484</td>
<td>0.56877</td>
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<td>R Squared</td>
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<td>2.72145</td>
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<td>Standard Error (Q/Ha)</td>
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<td>10.79856</td>
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<td>7.70642</td>
<td>6.90474</td>
<td>5.69849</td>
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</table>

Standard Deviation of Yields = 3.85906 Q/Ha

Yields and Climatic Data are Pooled Over Crop Regions 19 and 21
Missing for Western Kazakhstan
Meteorological Normals Based on 1958–1973

May 1977
**NORTHEASTERN URALS SPRING WHEAT MODEL**

**Region**

Northeastern Urals - Crop Region 20

P.E.T. A = .898  
P.E.T. I = 24.720  
June Daylength = 1.4448  
Latitude = 56°N

<table>
<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
<th>April</th>
<th>June</th>
<th>August</th>
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<tbody>
<tr>
<td>Overall Constant</td>
<td>1.00</td>
<td>9.37018</td>
<td>9.97322</td>
<td>12.72468</td>
<td>12.68680</td>
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<tr>
<td>Linear Trend (1958-1973)</td>
<td>16.00</td>
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<td>0.35404</td>
<td>0.03033</td>
<td>0.03479</td>
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<tr>
<td>Apr Prec (mm) DFN</td>
<td>23.56</td>
<td>0.08081</td>
<td>0.00936</td>
<td>0.01663</td>
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<tr>
<td>Jun Prec - P.E.T. (mm) DFN</td>
<td>-62.88</td>
<td>-0.09048</td>
<td>0.10930</td>
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<tr>
<td>Aug Prec (mm) DFN</td>
<td>55.88</td>
<td></td>
<td>-0.05692</td>
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</table>

R Squared  
Standard Error (Q/Ha)  
Standard Variance (Q/Ha)

| | | | | | |
| | | | | |
| 0.31550 | 0.38293 | 0.66771 | 0.76703 |
| 3.08486 | 3.03954 | 2.32156 | 2.03031 |
| 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 Based on 1958-1973  
YieldMeasured in Quintals per Hectare  
Meteorological Normals Based on 1958-1973

May 1977
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  
F.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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Constant</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Constant</td>
<td>DFN</td>
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<td>1.00</td>
<td>7.39502</td>
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<td>1.76968</td>
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<td>Apr Mean Temp (°C)</td>
<td>DFN</td>
<td>4.06</td>
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<td>-0.12129</td>
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<td>May Prec - P.E.T. (mm)</td>
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<td>-85.95</td>
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<td>Jul Mean Temp (°C)</td>
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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
Meteorological Normals Based on 1958-1971

May 1977
### 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

<table>
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<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Constant</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
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<tr>
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<td>Sep-Mar Prec (mm)</td>
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<td>-0.02072</td>
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<td>Apr Prec (mm)</td>
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<td>25.97</td>
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<td>Jul Prec - P.E.T. (mm)</td>
<td>SDFN</td>
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<td>Aug Prec (mm)</td>
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</table>

- **R Squared**: 0.00447  
- **Standard Error (Q/Ha)**: 3.89871  
- **Standard Variance (Q/Ha)**: 15.19996

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

May 1977
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

<table>
<thead>
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<th>Deviation</th>
<th>Normal</th>
<th>Constant</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
</tr>
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<tbody>
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<td>Sep-Apr Prec (mm)</td>
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<td>May Temp (°C)</td>
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<td>Jun Prec - P.E.T. (mm)</td>
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<td>Aug Prec (mm)</td>
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<tr>
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<tr>
<td>Standard Error (Q/Ha)</td>
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<tr>
<td>Standard Variance (Q/Ha)</td>
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<td>7.78739</td>
<td>6.59859</td>
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<td>2.26098</td>
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<tr>
<td>Standard Deviation of Yields</td>
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</tr>
</tbody>
</table>

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

May 1977
CENTRAL ASIA SPRING 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
June Daylength = 1.2373

Latitude = 40° N

<table>
<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Constant</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
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<tbody>
<tr>
<td>Overall Constant</td>
<td>DFN</td>
<td>1.00</td>
<td>5.85231</td>
<td>6.38719</td>
<td>6.78623</td>
<td>7.44896</td>
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<td>Apr Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>24.17</td>
<td>0.01504</td>
<td>0.00626</td>
<td>0.00780</td>
<td>0.00821</td>
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<td>Apr Prec - P.E.T. (mm)</td>
<td>SDFN</td>
<td>24.17</td>
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<td>May Prec - P.E.T. (mm)</td>
<td>DFN</td>
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<td>0.01943</td>
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<td>May Prec - P.E.T. (mm)</td>
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<td>Jun Prec - P.E.T. (mm)</td>
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<td>-0.00686</td>
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<td>Jun Prec - P.E.T. (mm)</td>
<td>SDFN</td>
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<td>-0.00179</td>
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<td>Jul Temp (°C)</td>
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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

May 1977
**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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
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<tbody>
<tr>
<td>Overall Constant</td>
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<td>1.00</td>
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<td>Linear Trend (1958-1972)</td>
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<td>15.00</td>
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<td>Mar-May Prec (mm)</td>
<td>DFN</td>
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<td>0.02360</td>
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<td>Jun Prec - P.E.T. (mm)</td>
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<td>Jul Temp (°C)</td>
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<td>-0.44442</td>
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<td>Aug Prec (mm)</td>
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<td>-0.03368</td>
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R Squared  

<table>
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<tr>
<th></th>
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<th>0.27949</th>
<th>0.30623</th>
<th>0.71120</th>
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<tbody>
<tr>
<td>Standard Error (Q/Ha)</td>
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<td>Standard Variance (Q/Ha)</td>
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<td>1.84026</td>
<td>1.67863</td>
<td>1.16790</td>
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</table>

Standard Deviation of Yields = 2.23757 Q/Ha

DFN = Departure from Normal  
SDFN = Squared Departure from Normal  
Yields Based on 1958-1972  
Meteorological Normal Based on 1958-1972  
Yields Measured in Quintals per Hectare

May 1977
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 (°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
Jul Prec - P.E.T. (mm) SDFN -31.37 -0.00025 -0.00037 -0.00052
Sep Prec (mm) DFN -11.88 0.00946 0.02187 0.02711

R Squared 0.53412 0.62293 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
Meteorological Normals Based on 1958-1972 for One Station - Blagoveschesk
Yields Measured in Quintals per Hectare

May 1977
### Northwest Spring Wheat Model

**Region**

Northwest - Crop Region 33

P.E.T. A = 0.897  
P.E.T. I = 24.646  
June Daylength = 1.4885  
Latitude = 58°N

<table>
<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
<th>April</th>
<th>June</th>
<th>July</th>
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</thead>
<tbody>
<tr>
<td>Overall Constant</td>
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<td>Jun Prec - P.E.T. (mm)</td>
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<td>Jul Temp (°C)</td>
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</table>

| 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 Based on 1958-1970 and 1972  
Meteorological Normals Based on 1958-1972  
Yields Measured in Quintals per Hectare