LARGE AREA CROP INVENTORY EXPERIMENT (LACIE)

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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).
RSFSR SPRING WHEAT YIELDS

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°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 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:

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

where:
\[ i = \text{year} \]
\[ j = \text{subregion}, j = 1, 2, \ldots, m \text{ and } m \text{ differs with models} \]
\[ k = \text{weather variable}, k = 1, \ldots, n \text{ and } n \text{ differs with models} \]
\[ Y_{ij} = \text{estimated yield for the } i\text{th year and } j\text{th subregion} \]
\[ \alpha_j = \text{constant for the } j\text{th subregion} \]
\[ \beta = \text{coefficient for trend, } T \]
\[ T_i = \text{trend for } i\text{th year} (1958=1, 1959=2, \ldots, 1973=16) \]
\[ \gamma_{jk} = \text{coefficient for } k\text{th weather variable } W_{ijk} \text{ where:} \]
\[ \text{These are the aridity index, temperature anomaly and/or precipitation anomaly or the square of one of these variables (these weather variables are based on monthly data only). The } k\text{th weather variable is not the same function for each model.} \]
\[ n = \text{the number of distinct weather variables and will vary by region} \]
\[ \epsilon_{ij} = \text{unexplained variation of the } i\text{th year and } j\text{th subregion} \]

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 \(m\).

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

\( I = \) heat index = \( \sum_{m=1}^{12} h_m \)

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

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

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

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

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

A-1
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
20. 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

<table>
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<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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<td>Overall Constant</td>
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<td>1.00</td>
<td>4.33592</td>
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<td>4.82387</td>
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<td>1.10882</td>
<td>1.10965</td>
<td>1.08025</td>
<td>1.07731</td>
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<td>0.68059</td>
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<td>May Prec - P.E.T. (mm)</td>
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<td>-0.02756</td>
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<td>Jun Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-56.21</td>
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<td>R Squared</td>
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<td>0.81682</td>
<td>0.85246</td>
<td>0.86025</td>
<td>0.86928</td>
<td>0.87596</td>
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<tr>
<td>Standard Error (Q/ha)</td>
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<td>2.63715</td>
<td>2.40863</td>
<td>2.38720</td>
<td>2.35275</td>
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<tr>
<td>Standard Variance (Q/ha)</td>
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<td>6.95458</td>
<td>5.80150</td>
<td>5.69874</td>
<td>5.53542</td>
<td>5.46273</td>
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</tbody>
</table>

Standard Deviation of Yields = 5.95955 Q/ha

DFN = Departure from Normal  
SDFN = Squared Departure from Normal  
Yields and Climatic Data are Pooled Over Crop Regions 1 and 2  
Yields Based on 1958-1973  
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
Latitude = 50°N
May Daylength = 1.2773
June Daylength = 1.3460

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 1.1158
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 -0.00063
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

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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<th>Deviation</th>
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<th>Trend</th>
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<th>March</th>
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<td>Apr Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-11.28</td>
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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

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
MOLDAVIA WINTER WHEAT MODEL

Region

Moldavia - Crop Region 8

March Daylength = .9808
April Daylength = 1.1251
Latitude = 47°N

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<th>July</th>
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<td>Constant</td>
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<tr>
<td>Linear Trend (1958-1973)</td>
<td>16.00</td>
<td>1.20124</td>
<td>1.36541</td>
<td>1.45563</td>
<td>1.56671</td>
<td>1.61532</td>
<td>1.88847</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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<tr>
<td>Apr Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-14.21</td>
<td>0.06763</td>
<td>0.06089</td>
<td>0.08502</td>
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<td>Jun Temp (°C)</td>
<td>DFN</td>
<td>18.86</td>
<td></td>
<td>-2.23464</td>
<td>-1.39325</td>
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<td>Jul Prec (mm)</td>
<td>DFN</td>
<td>60.63</td>
<td></td>
<td></td>
<td>-0.07373</td>
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</tbody>
</table>

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

<table>
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<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>
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<td>Sep-Mar Prec (mm)</td>
<td>DFN</td>
<td>233.75</td>
<td>0.02834</td>
<td>0.02759</td>
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<td>Nov-Mar Temp (°C)</td>
<td>DFN</td>
<td>-2.98</td>
<td>1.12799</td>
<td>0.92628</td>
<td>0.74880</td>
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<td>Nov-Mar Temp (°C)</td>
<td>SDFN</td>
<td>-2.98</td>
<td>-0.06090</td>
<td>-0.09846</td>
<td>-0.10528</td>
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<tr>
<td>Apr Temp (°C)</td>
<td>DFN</td>
<td>9.17</td>
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<td>0.50509</td>
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<td>Apr Temp (°C)</td>
<td>SDFN</td>
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<td>0.03074</td>
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<td>May Prec - P.E.T. (mm)</td>
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<td>-57.03</td>
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<td>-57.03</td>
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<td>-0.00141</td>
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</tr>
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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  
- **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

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<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>
<td>9.72778</td>
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<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>
<td>1.68806</td>
<td>1.85011</td>
<td>1.76580</td>
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<tr>
<td>Linear Trend (1958-1971)</td>
<td>14.00</td>
<td>0.47866</td>
<td>0.78932</td>
<td>0.70808</td>
<td>0.63560</td>
<td>0.64652</td>
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</tr>
<tr>
<td>Jan-Feb Temp (°C)</td>
<td>DFN</td>
<td>-7.76</td>
<td>0.84960</td>
<td>0.64729</td>
<td>0.36669</td>
<td>0.32586</td>
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</tr>
<tr>
<td>Mar Temp (°C)</td>
<td>DFN</td>
<td>-3.14</td>
<td>0.32550</td>
<td>0.70083</td>
<td>0.67848</td>
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<td>Apr Prec (mm)</td>
<td>DFN</td>
<td>36.00</td>
<td>0.03461</td>
<td>0.03232</td>
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<tr>
<td>Apr Prec (mm)</td>
<td>SDFN</td>
<td>36.00</td>
<td>0.00262</td>
<td>0.00274</td>
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<td>Apr Temp (°C)</td>
<td>SDFN</td>
<td>6.60</td>
<td>-0.17461</td>
<td>-0.16711</td>
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<td>May Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-43.95</td>
<td>0.22628</td>
<td>0.62085</td>
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<tr>
<td>R Squared</td>
<td>0.22628</td>
<td>0.62085</td>
<td>0.63946</td>
<td>0.75049</td>
<td>0.77045</td>
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<tr>
<td>Standard Error (Q/Ha)</td>
<td>3.83018</td>
<td>2.73651</td>
<td>2.72588</td>
<td>2.43180</td>
<td>2.39308</td>
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<tr>
<td>Standard Variance (Q/Ha)</td>
<td>14.67027</td>
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<td>7.43044</td>
<td>5.91366</td>
<td>5.72683</td>
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</table>

**Standard Deviation of Yields = 4.19001 Q/Ha**

DFN = 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 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>
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<td>6.6169</td>
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<td>Linear Trend (1958-1973)</td>
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<td>0.6539</td>
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<td>0.6237</td>
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<td>Dec-Mar Temp (°C)</td>
<td>DFN</td>
<td>0.3504</td>
<td>0.3503</td>
<td>0.3362</td>
<td>0.2512</td>
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<tr>
<td>Apr Temp (°C)</td>
<td>SDFN</td>
<td>5.31</td>
<td>-0.1861</td>
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<td>May Prec - P.E.T. (mm)</td>
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<td>-36.04</td>
<td>0.0350</td>
<td>0.0350</td>
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</table>

- R Squared: 0.71230 0.77284 0.82751 0.86092
- Standard Error (Q/Ha): 2.0481 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 Based on 1958-1973

Meteorological Normals Based on 1958-1973

Yields Measured in Quintals per Hectare

---

May 1977
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>
<tr>
<th>Variable</th>
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<th>Trend</th>
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<th>May</th>
<th>June</th>
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<tr>
<td>Overall Constant</td>
<td>1.00</td>
<td>8.70076</td>
<td>9.91247</td>
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<td>Apr Temp (°C)</td>
<td>DFN</td>
<td>3.81</td>
<td>0.18745</td>
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<td>SDFN</td>
<td>3.81</td>
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<td>May Prec - P.E.T. (mm)</td>
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<td>0.05659</td>
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<td>-55.99</td>
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<td></td>
<td>0.06491</td>
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<td>Jun Prec - P.E.T. (mm)</td>
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<td>-55.99</td>
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<td></td>
<td>-0.00118</td>
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</table>

R Squared = 0.35399
Standard Error (Q/Ha) = 2.67641
Standard Variance (Q/Ha) = 7.16317

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
<th>April</th>
<th>June</th>
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<tbody>
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<td>10.0964</td>
<td>10.3169</td>
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</tr>
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<td>Linear Trend (1958-1971)</td>
<td>12.00</td>
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<td>-66.26</td>
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<td>0.0486</td>
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</table>

- **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 Based on 1958-1971**

**Meteorological Normals Based on 1958-1971**

May 1977
MIDDLE VOLGA WINTER WHEAT MODEL

Region

Middle Volga - Crop Region 16

P.E.T. A = 1.058  May Daylength = 1.2994  Latitude = 52°N
P.E.T. I = 35.238

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<thead>
<tr>
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<th>Deviation</th>
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<th>May</th>
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<tbody>
<tr>
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<td>1.00</td>
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<td>DFN</td>
<td>6.23</td>
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<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>
<td>0.16253</td>
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</tr>
</tbody>
</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 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 = 0.874
- 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

<table>
<thead>
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<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
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</thead>
<tbody>
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<td>Jul Prec - P.E.T. (mm)</td>
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<tr>
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<tr>
<td>Standard Variance (Q/Ha)</td>
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</tbody>
</table>

- 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

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>
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<th>Deviation</th>
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<th>Trend April</th>
<th>Trend May</th>
<th>Trend June</th>
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<tbody>
<tr>
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<td>Linear Trend (1958-1974)</td>
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<td>0.48970</td>
<td>0.46731</td>
<td>0.47485</td>
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<td>Apr Prec (mm) DFN</td>
<td>26.82</td>
<td>-0.02195</td>
<td>-0.02818</td>
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<tr>
<td>Apr Prec (mm) SDFN</td>
<td>26.82</td>
<td>-0.00340</td>
<td>-0.00252</td>
<td>-0.00208</td>
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<tr>
<td>May Temp (°C) 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>
<td>0.00063</td>
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<tr>
<td>Jun Prec - P.E.T. (mm)</td>
<td>SDFN</td>
<td>-106.97</td>
<td>-0.00063</td>
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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

DEN = Departure from Normal
SDFN = 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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<th>Constant</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
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<tbody>
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<td>Overall Constant</td>
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<td>10.45508</td>
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<tr>
<td>Dec-Mar Temp (°C)</td>
<td>DFN</td>
<td>0.44</td>
<td>0.20381</td>
<td>0.16862</td>
<td>0.10457</td>
<td>0.15290</td>
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<tr>
<td>Apr Temp (°C)</td>
<td>DFN</td>
<td>12.86</td>
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<td>-0.16378</td>
<td>-0.21217</td>
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<td>Apr Temp (°C)</td>
<td>SDFN</td>
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<td>May Prec - P.E.T. (mm)</td>
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<td>0.06023</td>
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<td>SDFN</td>
<td>-44.62</td>
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<td>Jun Temp (°C)</td>
<td>DFN</td>
<td>23.21</td>
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<td>0.16862</td>
<td>0.10457</td>
<td>0.15290</td>
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R Squared = 0.00000
Standard Error (Q/Ha) = 3.00576
Standard Variance (Q/Ha) = 9.03459

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

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

<table>
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<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
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<th>April</th>
<th>May</th>
<th>June</th>
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<tbody>
<tr>
<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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<tr>
<td>Nov-Mar Prec (mm)</td>
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<td>241.71</td>
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<tr>
<td>Apr Prec - P.E.T. (mm)</td>
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<td>0.00123</td>
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<td>May Prec - P.E.T. (mm)</td>
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<td>0.01828</td>
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<td>Jun Temp (°C)</td>
<td>DFN</td>
<td>24.15</td>
<td></td>
<td></td>
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R Squared:

<p>| | | | | | | |</p>
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<tbody>
<tr>
<td></td>
<td>0.55286</td>
<td>0.67740</td>
<td>0.69627</td>
<td>0.75215</td>
<td>0.75529</td>
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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

Meteorological Normals Based on 1958-1974

May 1977
### NORTHWEST WINTER WHEAT MODEL

**Region**

Northwest - Crop Region 33

P.E.T. A = 0.891  
P.E.T. I = 24.247  
Latitude = 58°N

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

<table>
<thead>
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<th>Variable</th>
<th>Deviation</th>
<th>Normal</th>
<th>Trend</th>
<th>March</th>
<th>May</th>
<th>June</th>
<th>July</th>
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</thead>
<tbody>
<tr>
<td>Overall Constant</td>
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<td>1.00</td>
<td>8.25618</td>
<td>8.07855</td>
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<td>8.17219</td>
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<td>Linear Trend (1958-1971)</td>
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<td>14.00</td>
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<td>0.34996</td>
<td>0.35804</td>
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<td>Sep-Mar Prec (mm)</td>
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<td>-0.00303</td>
<td>0.00953</td>
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<tr>
<td>May Prec - P.E.T. (mm)</td>
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<td>-31.18</td>
<td>-0.00764</td>
<td>-0.00919</td>
<td>-0.01702</td>
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<td>Jun Prec - P.E.T. (mm)</td>
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<td>-0.00529</td>
<td>-0.01552</td>
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<td>Jul Prec - P.E.T. (mm)</td>
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<td>-61.54</td>
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<table>
<thead>
<tr>
<th>R Squared</th>
<th>Standard Error (Q/Ha)</th>
<th>Standard Variance (Q/Ha)</th>
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</thead>
<tbody>
<tr>
<td>0.59864</td>
<td>1.21037</td>
<td>1.46500</td>
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<tr>
<td>0.60864</td>
<td>1.25354</td>
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<td>0.62479</td>
<td>1.29380</td>
<td>1.67393</td>
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<td>0.63189</td>
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<tr>
<td>0.64303</td>
<td>0.88224</td>
<td>0.77834</td>
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</tbody>
</table>

- **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

Standard Deviation of Yields = 1.82919 Q/Ha

May 1977
### 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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<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>
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<td>1.00</td>
<td>9.33175</td>
<td>9.26464</td>
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<td>0.03112</td>
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<tr>
<td>Sep-Apr Prec (mm)</td>
<td>SDFN</td>
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<td>0.00010</td>
<td>0.00014</td>
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<td>Apr Mean Temp (°C)</td>
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<td>0.10724</td>
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<td>May Prec - P.E.T. (mm)</td>
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<tr>
<td>Jun Prec (mm)</td>
<td>DFN</td>
<td>46.47</td>
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<tr>
<td>Jul Prec - P.E.T. (mm)</td>
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<td>R Squared</td>
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<tr>
<td>Standard Variance (Q/Ha)</td>
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<td>8.77718</td>
<td>5.60186</td>
<td>5.67888</td>
<td>5.18885</td>
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**Standard Deviation of Yields = 3.38297 Q/Ha**

DFN = Departure from Normal  
SDFN = Squared Departure from Normal  
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

<table>
<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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<tbody>
<tr>
<td>Overall Constant</td>
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<td>6.95206</td>
<td>7.54990</td>
<td>7.86415</td>
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<td>0.80050</td>
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<td>0.67888</td>
<td>0.66978</td>
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<td>Jan-Feb Avg Temp (°C)</td>
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<td>Apr Mean Temp (°C)</td>
<td>DFN</td>
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<tr>
<td>May Prec (mm)</td>
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<td>0.06518</td>
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<tr>
<td>May Prec (mm)</td>
<td>SDFN</td>
<td>46.61</td>
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<td>-0.00167</td>
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<td>R Squared</td>
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<td>0.70732</td>
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<td>0.83343</td>
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<tr>
<td>Standard Error (Q/Ha)</td>
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<td>1.80531</td>
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<td>Standard Variance (Q/Ha)</td>
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<td>3.25915</td>
<td>2.73985</td>
<td>2.56914</td>
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</table>

### Notes

- **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 Spring Wheat Model

Region

Central District - Crop Region 13

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>
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<td>Jun Prec (mm)</td>
<td>SDFN</td>
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<td>Aug Prec (mm)</td>
<td>DFN</td>
<td>63.13</td>
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<td>Aug Prec (mm)</td>
<td>SDFN</td>
<td>63.13</td>
<td>-0.00180</td>
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<td></td>
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</table>

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
Yields Measured in Quintals per Hectare

Meteorological Normals Based on 1958-1973

May 1977
### Volga-Vyatsk Spring Wheat Model

**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>
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<th>Trend</th>
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<th>May</th>
<th>June</th>
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<tbody>
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<td>1.00</td>
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<td>Sep-Apr Prec (mm)</td>
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<td>Jun Prec - P.E.T. (mm)</td>
<td>DFN</td>
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<td>-55.99</td>
<td></td>
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<td>-0.00013</td>
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</table>

- 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 based on 1958-1973
Meteorological Normals based on 1958-1973
Yields measured in Quintals per Hectare

May 1977
The document provides data about the Upper Volga Spring Wheat Model, focusing on the Crop Region 15 in the Upper Volga area. The key parameters include:

- **P.E.T. A = .965**
- **P.E.T. I = 29.088**

**July Daylength = 1.3573**

**Latitude = 54°N**

### Variables

<table>
<thead>
<tr>
<th>Variable</th>
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<th>Trend</th>
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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

May 1977
### 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

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<thead>
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<th>Constant</th>
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<th>June</th>
<th>July</th>
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<td>9.82458</td>
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</table>

| R Squared                    |           | 0.00000 | 0.42909 | 0.62026 | 0.68602 |
| Standard Error (Q/Ha)        |           | 2.41340 | 1.89799 | 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 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

### Variable Deviation Normal Trend April May June

<table>
<thead>
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<th>Variable</th>
<th>Deviation</th>
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<th>Trend</th>
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<th>May</th>
<th>June</th>
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<td>Overall Constant</td>
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<td>6.24429</td>
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<td>0.04317</td>
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<td>-61.52</td>
<td>-0.00040</td>
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</table>

| 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 Based on 1958-1973  
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  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

<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>
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<tbody>
<tr>
<td>Overall Constant</td>
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<td>Crop Region 21 Constant</td>
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<td>Nov-Apr Prec (mm)</td>
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<td>Nov-Apr Prec (mm)</td>
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<td>Jun Prec - P.E.T. (mm)</td>
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<td>Jul Mean Temp (°C)</td>
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<td></td>
<td>-0.66473</td>
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</tr>
</tbody>
</table>

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 and Climatic Data are Pooled Over Crop Regions 19 and 21
Yields Measured in Quintals per Hectare

May 1977
**Northeastern Urals Spring Wheat Model**

**Region**

**Northeastern Urals - Crop Region 20**

\[ \text{P.E.T. A} = 0.898 \quad \text{June Daylength} = 1.4448 \quad \text{Latitude} = 56^\circ \text{N} \]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Deviation</th>
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<th>Trend</th>
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<th>June</th>
<th>August</th>
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<td>Overall Constant</td>
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<tr>
<td>Linear Trend (1958-1973)</td>
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<td>0.35404</td>
<td>0.03033</td>
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<tr>
<td>Apr Prec (mm)</td>
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<td>0.00936</td>
<td>0.00936</td>
<td>0.01663</td>
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</tr>
<tr>
<td>Jun Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-0.08081</td>
<td>0.00936</td>
<td>0.00936</td>
<td>0.01663</td>
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</tr>
<tr>
<td>Aug Prec (mm)</td>
<td>DFN</td>
<td>0.00936</td>
<td>-0.08081</td>
<td>0.00936</td>
<td>0.01663</td>
<td></td>
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</tbody>
</table>

\[ \text{R Squared} = 0.31550 \quad \text{0.38293} \quad \text{0.66771} \quad \text{0.76703} \]

\[ \text{Standard Error (Q/Ha)} = 3.08486 \quad 3.03954 \quad 2.32156 \quad 2.03031 \]

\[ \text{Standard Variance (Q/Ha)} = 9.51633 \quad 9.23880 \quad 5.38965 \quad 4.12215 \]

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

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**

- 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>
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<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>
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<tr>
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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 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

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<th>Constant</th>
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<th>April</th>
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<tr>
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</tr>
<tr>
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<td>0.12189</td>
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<td>Aug Prec (mm)</td>
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</table>

| 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 Deviation of Yields = 3.83949 (Q/Ha)

DFN = Departure from Normal  
SDFN = Squared Departure from Normal  
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

<table>
<thead>
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<th>Deviation</th>
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<th>Constant</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
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</thead>
<tbody>
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<td>Overall Constant</td>
<td>DFN</td>
<td>1.00</td>
<td>8.20883</td>
<td>8.22386</td>
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<td>8.09219</td>
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<td>Sep-Apr Prec (mm)</td>
<td>DFN</td>
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<td>0.06256</td>
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</table>

**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

**Yields Based on 1958-1968 and 1971-1974**

SDFN = Squared Departure from Normal

**Meteorological Normals Based on 1957-1974**

Yields Measured in Quintals per Hectare

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>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Constant</td>
<td></td>
<td>1.00</td>
<td>5.85231</td>
<td>6.33719</td>
<td>6.78623</td>
<td>7.44896</td>
<td>7.43362</td>
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<tr>
<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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</tr>
<tr>
<td>Apr Prec - P.E.T. (mm)</td>
<td>SDFN</td>
<td>24.17</td>
<td>-0.00040</td>
<td>-0.00040</td>
<td>-0.00050</td>
<td>-0.00049</td>
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</tr>
<tr>
<td>May Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-52.30</td>
<td>0.01943</td>
<td>0.01957</td>
<td>0.01872</td>
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<td></td>
</tr>
<tr>
<td>May Prec - P.E.T. (mm)</td>
<td>SDFN</td>
<td>-52.30</td>
<td>-0.00044</td>
<td>-0.00061</td>
<td>-0.00060</td>
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<td></td>
</tr>
<tr>
<td>Jun Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-121.27</td>
<td>-0.00686</td>
<td>-0.00755</td>
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<td></td>
</tr>
<tr>
<td>Jun Prec - P.E.T. (mm)</td>
<td>SDFN</td>
<td>-121.27</td>
<td>-0.00179</td>
<td>-0.00178</td>
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<td></td>
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</tr>
<tr>
<td>Jul Temp (°C)</td>
<td>DFN</td>
<td>25.94</td>
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<td>-0.06632</td>
</tr>
</tbody>
</table>

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

<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>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Constant</td>
<td>1.00</td>
<td>9.21112</td>
<td>9.32541</td>
<td>10.17852</td>
<td>10.23747</td>
<td>9.68920</td>
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</tr>
<tr>
<td>Linear Trend (1958-1972)</td>
<td>15.00</td>
<td>0.26451</td>
<td>0.25022</td>
<td>0.14358</td>
<td>0.13621</td>
<td>0.20475</td>
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</tr>
<tr>
<td>Mar-May Prec (mm)</td>
<td>DFN</td>
<td>0.01594</td>
<td>0.02360</td>
<td>0.02315</td>
<td>0.02315</td>
<td>0.02714</td>
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</tr>
<tr>
<td>Jun Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>0.07714</td>
<td>0.05760</td>
<td>0.05760</td>
<td>0.05760</td>
<td>0.06060</td>
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</tr>
<tr>
<td>Jul Temp (°C)</td>
<td>DFN</td>
<td>19.12</td>
<td>0.14358</td>
<td>0.14358</td>
<td>0.14358</td>
<td>0.14358</td>
<td></td>
</tr>
<tr>
<td>Aug Prec (mm)</td>
<td>DFN</td>
<td>60.80</td>
<td>-0.44442</td>
<td>-0.44442</td>
<td>-0.44442</td>
<td>-0.44442</td>
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</tbody>
</table>

<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>
</tr>
</thead>
<tbody>
<tr>
<td>R Squared</td>
<td></td>
<td>0.27949</td>
<td>0.30623</td>
<td>0.71120</td>
<td>0.76052</td>
<td>0.85004</td>
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<tr>
<td>Standard Error (Q/Ha)</td>
<td></td>
<td>1.97101</td>
<td>2.01307</td>
<td>1.35656</td>
<td>1.29562</td>
<td>1.08070</td>
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<tr>
<td>Standard Variance (Q/Ha)</td>
<td></td>
<td>3.88489</td>
<td>4.05244</td>
<td>1.84026</td>
<td>1.67863</td>
<td>1.16790</td>
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</tr>
</tbody>
</table>

**Standard Deviation of Yields = 2.23757 Q/Ha**

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

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

<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>September</th>
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<tbody>
<tr>
<td>Overall Constant</td>
<td>1.00</td>
<td>5.47145</td>
<td>5.99671</td>
<td>6.47163</td>
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<tr>
<td>Linear Trend (1958-1972)</td>
<td>15.00</td>
<td>0.37941</td>
<td>0.29597</td>
<td>0.33527</td>
<td>0.36973</td>
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<tr>
<td>May Temp (°C)</td>
<td>11.48</td>
<td>0.76039</td>
<td>0.48272</td>
<td>0.08222</td>
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<tr>
<td>Jun Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-31.37</td>
<td>0.01584</td>
<td>-0.00025</td>
<td>-0.00037</td>
<td>-0.00052</td>
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</tr>
<tr>
<td>Jul Prec - P.E.T. (mm)</td>
<td>SDFN</td>
<td>-31.37</td>
<td>0.01990</td>
<td>0.02472</td>
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<td>Sep Prec (mm)</td>
<td>DFN</td>
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<td>0.02187</td>
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<tr>
<td>R Squared</td>
<td></td>
<td>0.53412</td>
<td>0.62298</td>
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<tr>
<td>Standard Error (Q/Ha)</td>
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<td>1.65844</td>
<td>1.55826</td>
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<tr>
<td>Standard Variance (Q/Ha)</td>
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<td>1.79658</td>
<td>1.40136</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 1970-1972*  
*Meteorological Normals Based on 1958-1972 for One Station - Blagoveschesk*

May 1977
## NORTHWEST SPRING WHEAT MODEL

**Region**

Northwest - Crop Region 33

P.E.T. A = .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>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Constant</td>
<td>1.00</td>
<td>4.41524</td>
<td>4.48170</td>
<td>5.13108</td>
<td>5.18313</td>
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<tr>
<td>Linear Trend (1958-1972)</td>
<td>15.00</td>
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<td>0.45822</td>
<td>0.45239</td>
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<tr>
<td>Apr Prec (mm)</td>
<td>DFN</td>
<td>34.80</td>
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<td>0.01411</td>
<td>0.01132</td>
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</tr>
<tr>
<td>Jun Prec - P.E.T. (mm)</td>
<td>DFN</td>
<td>-66.10</td>
<td>0.01664</td>
<td>0.01306</td>
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<td></td>
</tr>
<tr>
<td>Jun Prec - P.E.T. (mm)</td>
<td>SDFN</td>
<td>-66.10</td>
<td>-0.00059</td>
<td>-0.00059</td>
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<td></td>
</tr>
<tr>
<td>Jul Temp (°C)</td>
<td>DFN</td>
<td>17.57</td>
<td>5.13108</td>
<td>5.18313</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[R \text{ Squared} = 0.64011, \text{ Standard Error (Q/Ha)} = 1.57275, \text{ Standard Variance (Q/Ha)} = 2.47355\]

\[\text{Standard Deviation of Yields} = 2.51880 \text{ Q/Ha}\]

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

NASA-JSC  
May 1977