GEORGE HANUSCHAK'S COPY

LACIE-00430

JSC-11343

LARGE AREA CROP INVENTORY EXPERIMENT (LACIE)

NASA NOAA USDA

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

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

January, 1976

DOCUMENT

PREPARED BY

NOAA/USDA PERSONNEL

CENTER FOR CLIMATIC AND ENVIRONMENTAL ASSESSMENT

COLUMBIA, MISSOURI

TECHNICAL NOTE 76-1

JANUARY 1976

Jerry D. Hill

Authorized by
for Norton D. Strommen
Acting Director, CCEA
October 20, 1976

ACKNOWLEDGMENT

The authors are pleased to recognize the supporting staff at the Center for Climatic and Environmental Assessment for their assistance in the completion of this project and report. Rita Fobian, Rita Terry, Jeanne Beare, Nancy Beever, and Paula Rosenkoetter were helpful in data analysis, drafting, typing and editing of the work contained herein. It would have been difficult to complete this study in the allocated time without them.

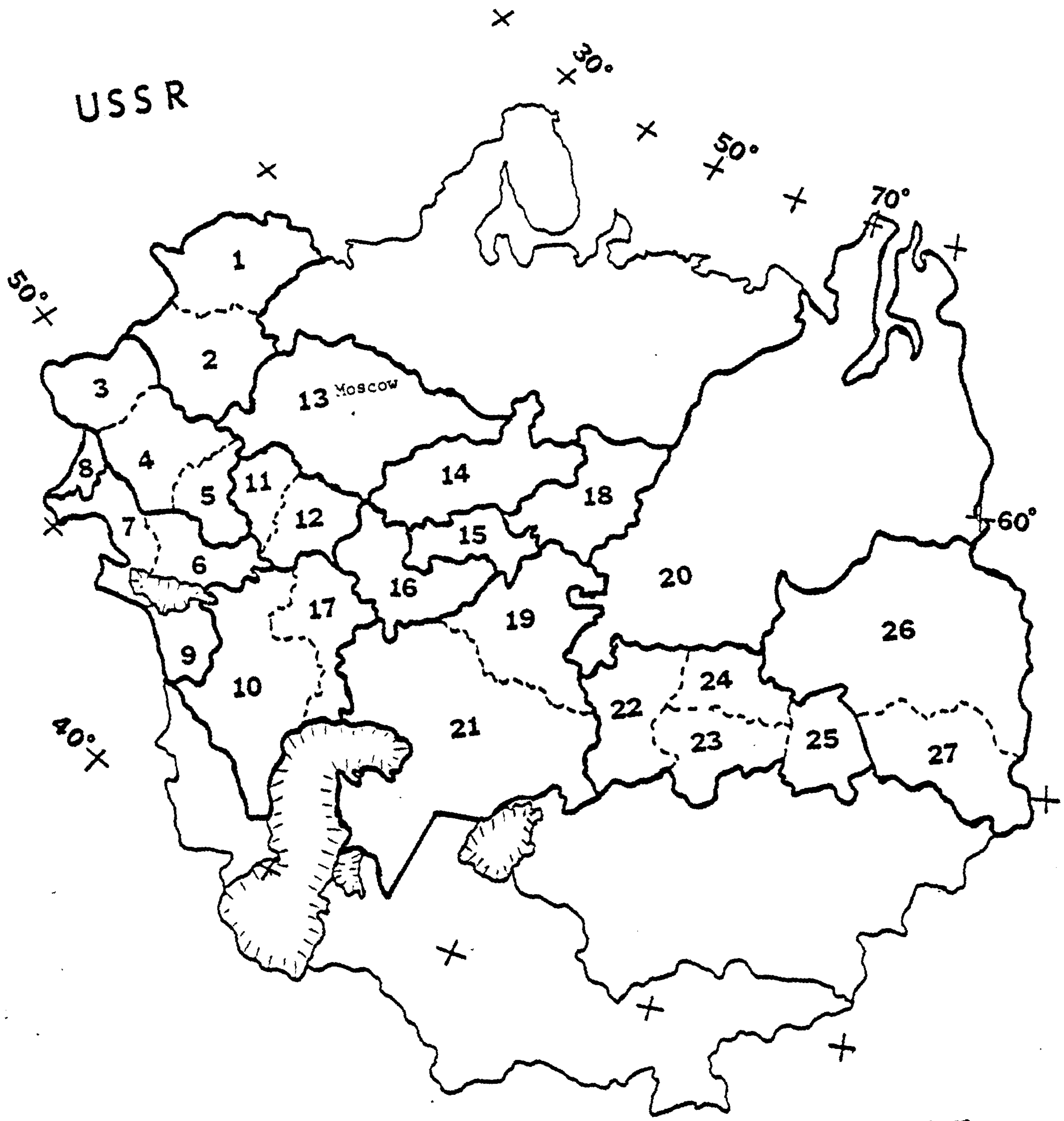


Figure 1. Crop regions showing areas for which wheat models have been developed. The hatched lines within a darkened line area show the inclusion of more than one crop region in a single model.

Meteorological Organization (WMO) climatological 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 concerned.

Factors Affecting Wheat Production

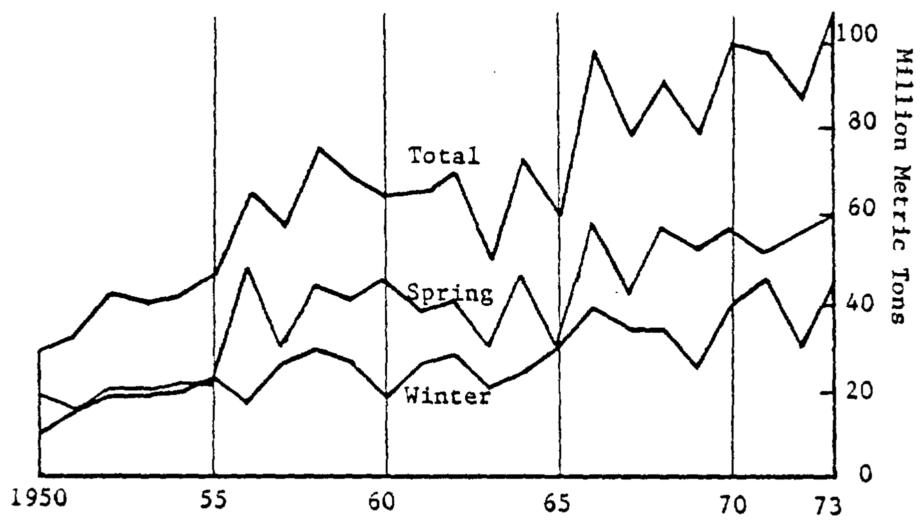
The U.S.S.R. grows approximately one-fourth of the world wheat production (Bureau of Agricultural Economics, 1974). Winter wheat is grown primarily in European U.S.S.R. Spring wheat is the principal wheat grown in Asiatic U.S.S.R. Production of all wheat increased 40 percent from 1959-64 to 1969-73. However, planted wheat acreage and harvested acreage has changed little since 1955 (Figure 2). Hence, the increased production is 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, with the remainder to winter wheat. Figure 2 also 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 occurring 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 yields include improved variaties, increased mechanization, greater fertilizer use, irrigation of more acres, application of pesticides on more hectares, etc.

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

USSR WHEAT

PRODUCTION



AREA SOWN

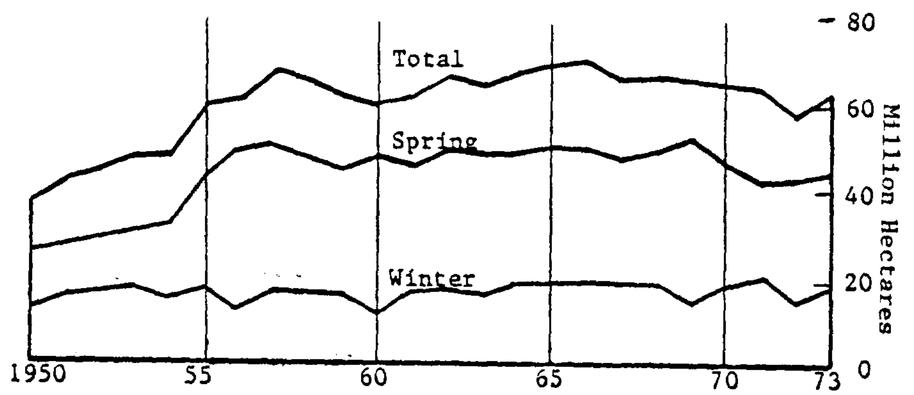


Figure 2. March of production and spring and winter wheat sown area in the U.S.S.R. from 1950-1973 (source: CIA, 1974).

RSFSR SPRING WHEAT YIELDS

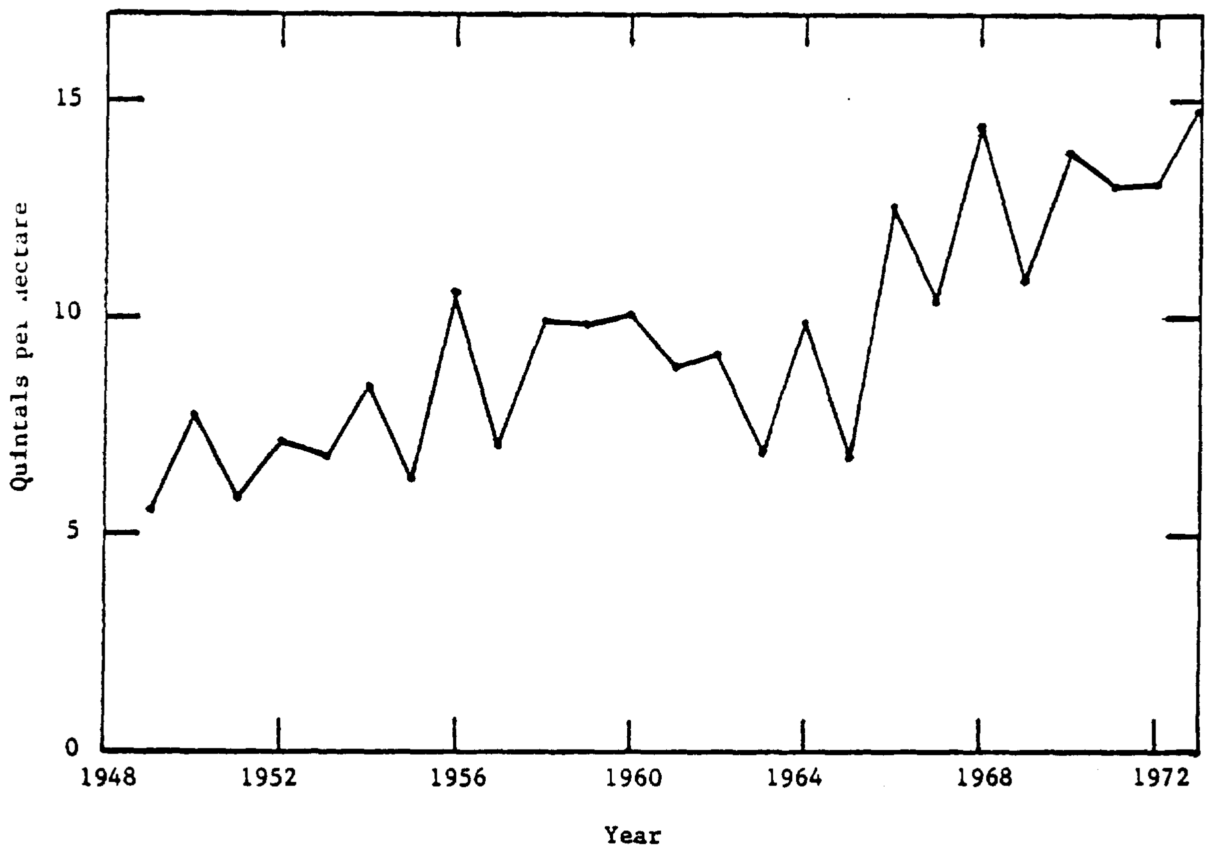


Figure 3. Spring wheat yield in the Russian Soviet Federated Socialist Republic (RSFSR), 1949-1972 (data: Manellya, et. al., 1972).

RSFSR WINTER WHEAT YIELDS

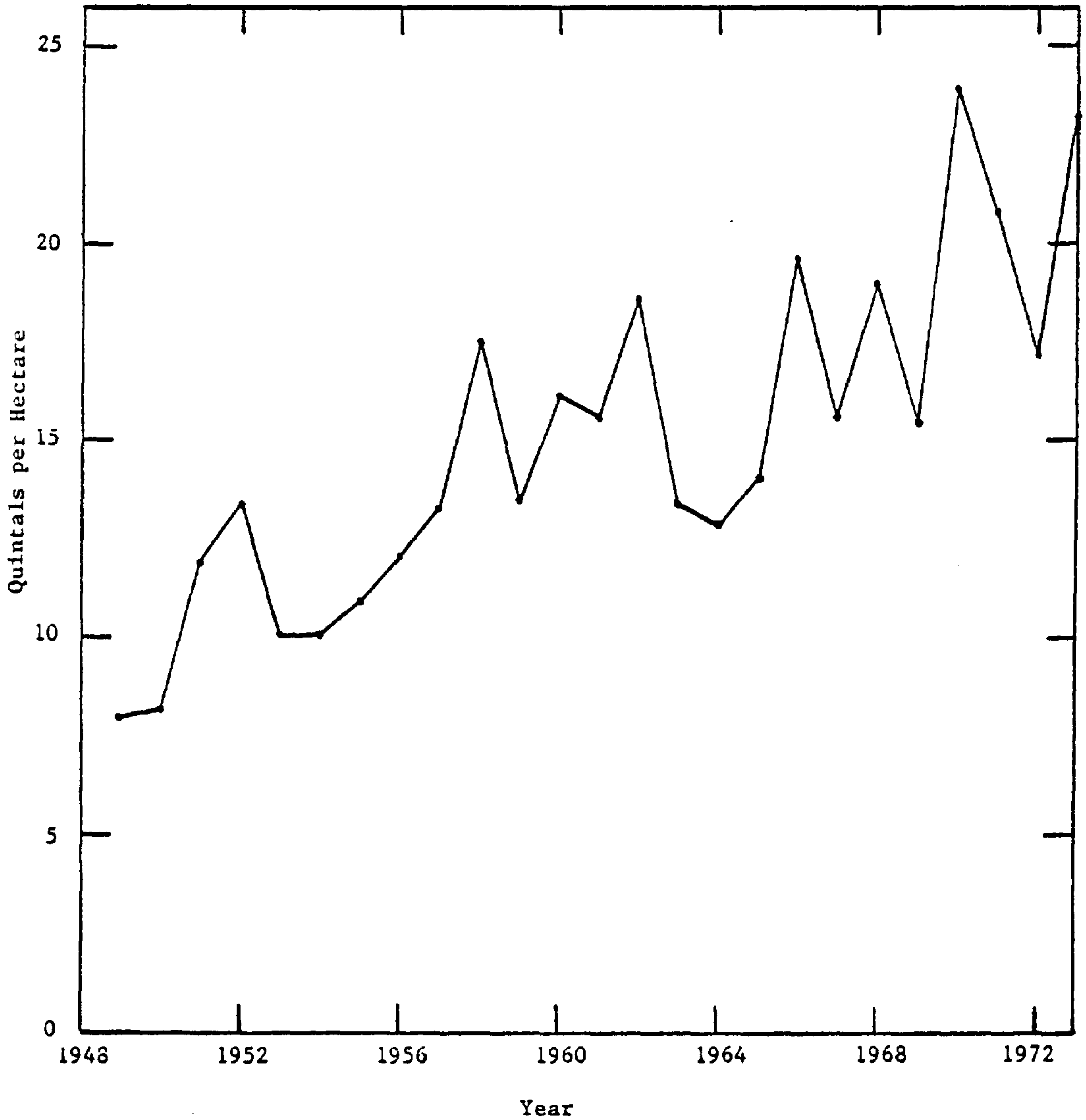


Figure 4. Winter wheat yield in the Russian Soviet Federated Socialist Republic (RSFSR), 1949-1972 (data: Manellya, et. al., 1972).

Wheat grown in the U.S.S.R. covers a wide range of climate. The distance from the northern and southern latitude 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, Regions 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 Kazakhastan 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 largely 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 much as when stress occurs during the heading period (Bauer, 1972; Panomarev, 1962). High temperature can also be detrimental to wheat production. Temperatures above $32^{o}C$ ($90^{o}F$) can hurt wheat crop yield during critical periods such as flowering (Jensen and Lund, 1971; Kogan, 1966: Panomarev, 1962).

Low temperatures affect the wheat plant differently depending on the growth stage and variety. Areas with a continental climate, particularly in European U.S.S.R., have the highest probability of wheat being damaged by low temperature. 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 of the duration of the low temperature as well as the variety involved.

A phenomenon which can also reduce wheat yield is 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 Kazakhastan, 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 wilts even though moisture is present in the soil. The relative humidity at night during a sukhovei is sometimes lower than during a drought (Borisov, 1959). The frequency of the sukhovei resembles a drought frequency chart in scope as well as in percentage (Figure 5 after Alpatev in Vitkevich 1960).

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

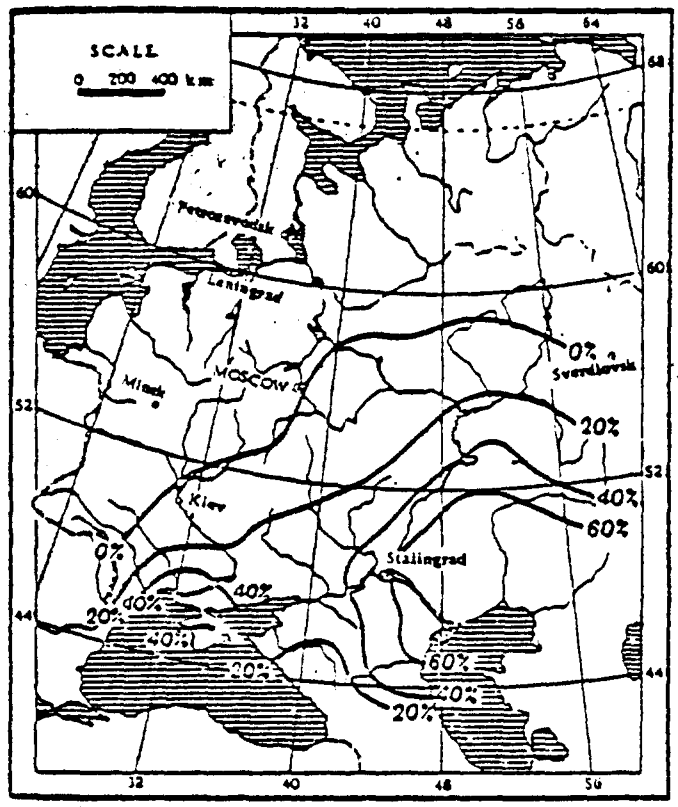
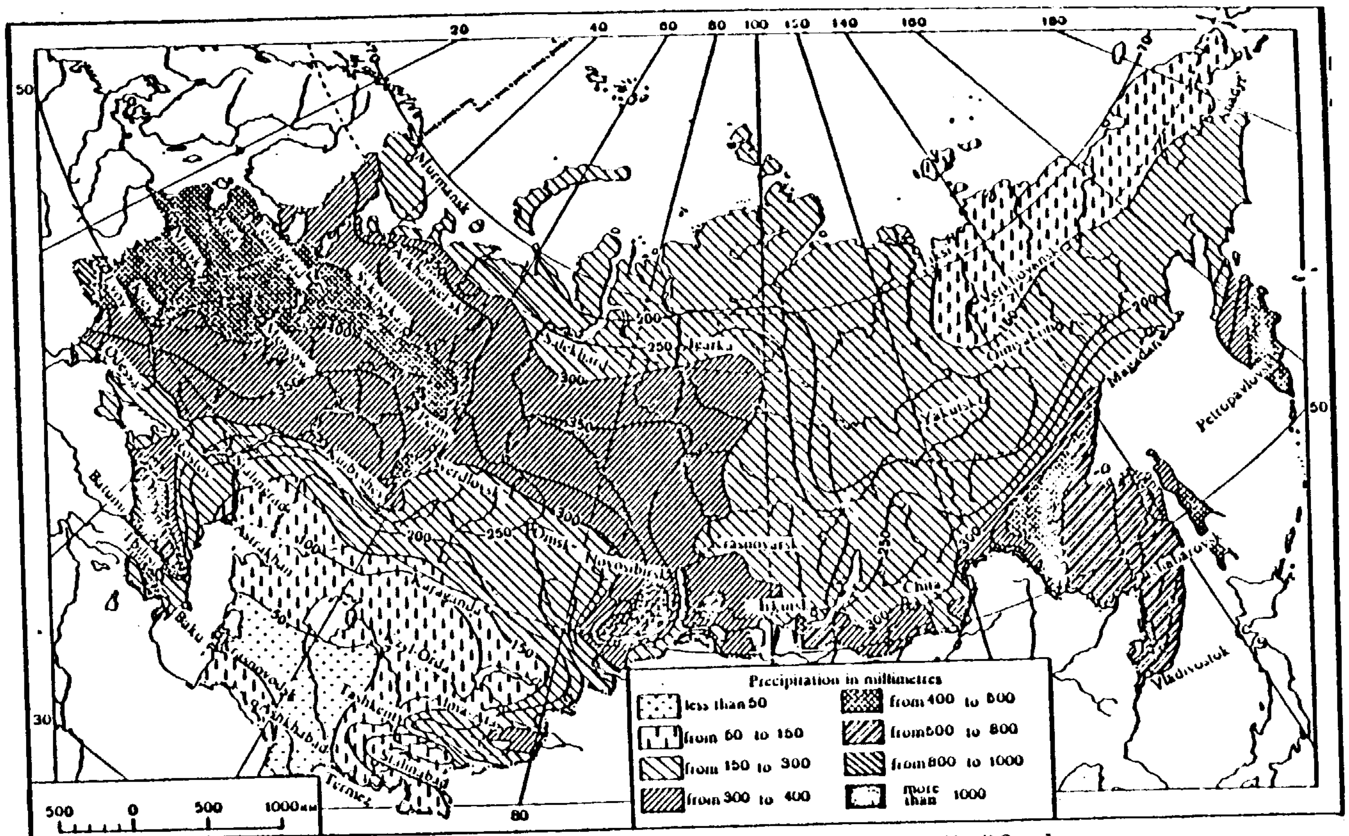


Figure 5. Drought Frequency Chart in the U.S.S.R. (source: Vitkevich, 1960).



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

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

harvesting operations. Also, in these areas low temperatures and frost can reduce yield substantially (Jokovlev, 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 Kazakhastan, 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.

<u>The Regression Models</u>

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

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

where:

i = year

j = subregion, j = 1, 2, ..., m and m differs with models

k = weather variable, k = 1, ..., n and n differs with models

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

α_j = constant for the jth subregion

β = coefficient for trend, T

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

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

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

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

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

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

The Weather Variables

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

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

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

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

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

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

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

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

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

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

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

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

Selection of Weather Variables

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

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

The selection of weather variables usually began with determining a preseason variable such as total precipitation from September through April (preseason moisture) for spring wheat. The months included for preseason moisture varied with regions (e.g., September through March or November through March). In some areas such as the Kazakhastan 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 that period 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 its inclusion was determined 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. Testing of the models is the next procedure.

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 the 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

Australia, Bureau of Agricultural Economics, 1974: Wheat Situation and Outlook. Canberra.

Bauer, A., 1972: Effect of Water Supply and Seasonal Distribution on Spring Wheat Yields. Bulletin 490, North Dakota Agricultural Experiment Station, Fargo.

Bogdanov, T. F., 1965: The Dependence of the Spring Wheat Yield on the Amount of Precipitation in the Central Non-Chernozem Zone. Meteorologiya i Gidrologiya, 7:46-48. (in Russian)

Borisov, A. A., 1959: Climates of the U.S.S.R., ed. by C. A. Halstead, trans. by R. A. Ledward. Chicago, Aldine.

Central Intelligence Agency, 1974: U.S.S.R. Agriculture Atlas. Washington, December.

Jakovlev, N. N., 1973: Agrometeorological Factors Influencing Spring Wheat Yield and Grain Quality in the Soviet Socialist Republics. Plant Response to Climatic Factors, Proceedings of the Uppsala Symposium, ed. by R. O. Slayter, Paris, UNESCO.

Jensen, L. A., and H. R. Lund, 1971: How Cereal Crops Grow. Extension Bulletin Number 3, North Dakota State University, Fargo.

Kogan, F. N., 1966: Estimate of the Summer Wheat Yield by Meteorological Data in Regions with a Clearly Continental Climate. Meteorologiya i Gidrologiya, 10: 14-18. (in Russian)

Manellya, A. I., N. N. Nagnibelova, A. A. Frenkel, and L. I. Vashchukov, 1972: Dinamika Urozhaynosti Sel'skokhozyaystvennykh Kul'tur v RSFSR (Dynamics of Agricultural Crop Yields in the RSFSR). Moscow, Statistika.

Martin, J. H., and W. H. Leonard, 1949: Principles of Field Crop Production. New York, McMillan.

Palmer, W. C., and A. V. Havens, 1958: A Graphical Technique for Determining Evapotranspiration by the Thornthwaite Method. Monthly Weather Review.

Panomarev, B. P., 1962: An Appraisal of Agro-Meteorological Conditions of Spring Wheat Production in the Steppe anf Forest-Steppe Zones of the RFSFR. Transactions Tsentr Institute, Prognozov, 101:3-24. (in Russian)

Pope, Fletcher, Jr., V. Zabijaka, and W. Ragsdale, 1973: Agriculture in the United States and the Soviet Union. FAS Report Number 92. Washington, U.S. Department of Agriculture, Economic Research Service.

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

Ulanova, E. S., 1966: The Effect of May Precipitation on Yields of Winter Wheat in the Steppe Regions of the Ukraine and Northern Caucasus. Meteorologiya i Gidrologiya, 5:17-25.

U.S. Department of Commerce, Environmental Science Services Administration, 1966: World Weather Records, Vol. 2, Europe. Washington.

U.S. Department of Commerce, Environmental Science Services Administration, 1967: World Weather Records, Vol 4., Asia. Washington.

Vitkevich, V. I., 1960: Agricultural Meteorology. Jerusalem, Israel Program for Scientific Translation.

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

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 Kazakhastan
25. Pavlodar

Siberia-Altai

26. Western Siberia
27. Altai Kray

BALTICS-BELORUSSIA WINTER WHEAT COVARIANCE MODEL

Region: Crop Region 1 (Baltics) and Crop Region 2 (Belorussia).
Data Base: 1958-73.
Normals are based on entire time period.
Yields and climatic data are pooled over Crop Regions 1 and 2.
Yield data are measured in centners per hectare.
Potential evapotranspiration is estimated using Thornthwaite's method (I=27.823, A=0.946).
Average monthly daylength is for latitude 55°N (April=1.19, May=1.37, June=1.45).

Variable	Coding
Overall Constant	=1
Crop Region 2 Constant	=1 if data from Crop Region 2; otherwise = 0
Linear Trend, 1958-73	1958=1, 1959=2, ..., 1973=16
December through March average temp (°C)	Departure from Normal (Normal=-4.1°C)
April prec - P.E.T. (mm)	Departure from Normal (Normal=1.54 mm)
May prec - P.E.T. (mm)	Departure from Normal (Normal=-33.7 mm)
June prec - P.E.T. (mm)	Departure from Normal (Normal=-58.4 mm)

TRUNCATED MODELS FOR BALTICS-BELORUSSIA WINTER WHEAT (1958-73)

Variable		Trend	Truncation Time: March	April	May	June
Overall Constant		4.34	4.55	4.85	4.79	4.80
Crop Region 2 Constant		2.81	2.33	2.19	2.36	2.36
Linear Trend, 1958-73		1.11	1.11	1.08	1.08	1.08
Dec thru Mar average temp (°C)	DFN		0.532	0.621	0.711	0.689
Apr prec - P.E.T. (mm)	DFN			0.037	0.038	0.047
May prec - P.E.T. (mm)	DFN				-0.032	-0.020
Jun prec - P.E.T. (mm)	DFN					0.023
Standard Error		2.65	2.46	2.44	2.39	2.39
R^2		0.81	0.85	0.85	0.865	0.871
Adjusted R^2		0.80	0.83	0.83	0.84	0.84

Standard Deviation of Yield = 5.97

DFN = Departure from Normal
SDFN = Squared Departure from Normal

NORTH UKRAINE WINTER WHEAT COVARIANCE MODEL

Region: Crop Region 3 (West Ukraine), Crop Region 4 (North Central Ukraine), Crop Region 5 (Northeast Ukraine).
Data Base: 1958-73
Yield and climatic data are pooled over Crop Regions 3, 4, and 5.
Normals are based on the entire time period.
Yield data is measured in centners per hectare.
Potential Evapotranspiration (P.E.T.) is estimated using Thornthwaite's method (A = 1.031, I = 33.490).
Average monthly daylength is for latitude 50° N (daylength factors: April (1.15), May (1.33), June (1.36)).

VARIABLE	CODING
Overall Constant	=1
Crop Region 3 Constant	=1 if data from Crop Region 3 =0 otherwise
Crop Region 4 Constant	=1 if data from Crop Region 4 =0 otherwise
Linear Trend, 1958-73	1958=1, 1959=2, ..., 1973=16
September to March total Prec. (mm)	Departure from Normal (Normal=284.3 mm)
December to March Average Temp. (°C)	Departure from Normal (Normal=-3.0°C) Squared Departure from Normal
April Prec. - P.E.T. (mm)	Departure from Normal (Normal=-7.4 mm)
May Prec. - P.E.T. (mm)	Departure from Normal (Normal=-40.3 mm) Squared Departure from Normal
June Prec. - P.E.T. (mm)	Departure from Normal (Normal=-53.6 mm) Squared Departure from Normal

TRUNCATED MODELS FOR NORTH UKRAINE WINTER WHEAT (1958-73)

VARIABLE		TRUNCATION TIME TREND	MARCH	APRIL	MAY	JUNE
Overall Constant		14.014	15.444	15.535	16.572	19.100
Crop Region 3 Constant		-1.112	-3.824	-4.779	-5.336	-6.746
Crop Region 4 Constant		0.406	-1.121	-1.328	-1.476	-1.484
Linear Trend, 1958-73		0.909	1.017	1.030	0.984	0.846
September to March Prec. (mm)	DFN	------	-0.021	-0.023	-0.021	-0.022
December to March Temp. (°C)	DFN	------	1.304	1.457	1.383	1.014
	SDFN	------	-0.282	-0.228	-0.205	-0.230
April Prec. - P.E.T. (mm)	DFN	------	------	0.047	0.057	0.016
May Prec. - P.E.T. (mm)	DFN	------	------	------	0.023	0.047
	SDFN	------	------	------	-0.00052	-0.00072
June Prec. - P.E.T. (mm)	DFN	------	------	------	-------	0.048
	SDFN	------	------	------	-------	-0.00044
Standard Error (cent/hect)		3.76	2.88	2.80	2.73	2.50
R^2		0.58	0.77	0.79	0.81	0.85
Adjusted R^2		0.55	0.74	0.75	0.76	0.80

Standard Deviation of Yields =5.62 cent/hect

DFN = Departure From Normal
SDFN = Squared Departure From Normal

UKRAINE-KRASNODAR WINTER WHEAT COVARIANCE MODEL

Region: Crop Region 6 (Eastern Ukraine), Crop Region 7 (Southern Ukraine), and Crop Region 9 (Krasnodar).
Data Base: 1958-1972
Yield and climatic data are pooled over Crop Regions 6, 7, and 9.
Normals are based on the entire time period.
Yield data is measured in centners per hectare.
Potential evapotranspiration is estimated using Thornthwaite's method (A=1.206, I=45.144).
Average monthly daylength is for latitude 47°N (Daylength factor: April 1.14).

VARIABLE	CODING
Overall Constant	=1
Crop Region 6 Constant	=1 if data from Crop Region 6 =0 otherwise
Crop Region 7 Constant	=1 if data from Crop Region 7 =0 otherwise
Linear Trend, 1958-72	1958=1,1959=2,...,1972=15
January to February Average Temp. (°C)	Departure From Normal (Normal = -2.3°C) Squared Departure From Normal
September-March Total Prec. (mm)	Departure From Normal (Normal = 299.0 mm)
April Prec. - PET (mm)	Departure From Normal (Normal = -11.9 mm)

TRUNCATED MODELS FOR UKRAINE-KRASNODAR WINTER WHEAT (1958-72)

VARIABLE	TREND	TRUNCATION TIME FEBRUARY	MARCH	APRIL
Overall Constant	22.074	18.120	17.970	17.020
Crop Region 6 Constant	-6.067	-1.832	-1.511	-1.131
Crop Region 7 Constant	-5.347	-4.710	-4.112	-3.647
Linear Trend, 1958-72	.569	.931	.911	.999
January-February Average Temp. (°C) DFN	---	1.266	1.190	1.248
January-February Average Temp. SDFN	---	-.064	-.064	-.068
September-March Prec. (mm.) DFN	---	---	.008	.009
April Prec. - PET (mm.) DFN	---	---	---	.038
Standard Error (cent/hect)	4.090	2.750	2.750	2.670
R^2	.470	.770	.780	.800
Adjusted R^2	.430	.740	.740	.760

Standard Deviation of Yield = 5.41 cent/hect

DFN = Departure From Normal
SDFN = Squared Departure From Normal

REVIS'

MOLDAVIA WINTER WHEAT MODEL - REGION 8

Years: 1958-73
Trend: 1958=1, 1959=2, ..., 1973=16
Thornthwaite's method used for P.E.T., A=1.206, I=45.144.
Daylength correction factor is for Latitude 47°N (March=1.01, April=1.14).

			Coefficients for Truncated Models					
Variable		Normal	Trend	February	March	April	June	July
Constant			10.492	9.148	8.321	7.403	6.947	4.887
Trend			1.2024	1.3605	1.458	1.566	1.619	1.862
Jan-Feb Avg Temp (°C)		-2.3		1.2592	1.220	1.273	0.853	0.849
Mar Prec-P.E.T. (mm)	C=1.01 DFN	21.3			-0.070	-0.078	-0.156	-0.115
Apr Prec-P.E.T. (mm)	C=1.14 DFN	-13.9				0.067	0.060	0.081
Jun Temp (°C)	DFN	18.9					-2.356	-1.562
Jul Prec (mm)	DFN	60.5						-0.066
Se			5.88	5.23	5.19	5.03	4.63	4.59
R^2			0.50	0.64	0.67	0.71	0.78	0.81
R^2 (Adjusted)			0.47	0.58	0.59	0.61	0.67	0.68

Standard Deviation of Yield = 8.064

DFN is Deviation from Normal
SDFN is Squared Deviation from Normal

REVISED

CAUCASUS - VOLGA WINTER WHEAT COVARIANCE MODEL

Region: Crop Region 10 (Northeastern Caucasus) and Crop Region 17 (Lower Volga).
Data Base: 1958-71
Normals are based on the entire time period.
Yield and climatic data are pooled over Crop Regions 10 and 17.
Yield data is measured in centners per hectare.
Potential Evapotranspiration is estimated using Thornthwaite's method (A = 1.183, I = 43.565).
Average monthly daylength is for latitude 48°N (Daylength factors: May (1.31)).

Variable	Coding
Overall Constant	=1
Crop Region 10	=1 if data from Crop Region 10 =0 otherwise
September to March total Prec. (mm)	Departure from Normal (Normal = 232.9 mm)
November to March average Temp. (°C)	Departure from Normal (Normal = -2.8°C) Squared Departure from Normal
April Temp (°C)	Departure from Normal (Normal = 9.4°C) Squared Departure from Normal
May Prec. - P.E.T. (mm)	Departure from Normal (Normal = -58.2 mm) Squared Departure from Normal

TRUNCATED MODELS FOR CAUCASUS - VOLGA WINTER WHEAT (1958-71)

VARIABLE		TREND*	TRUNCATION TIME MARCH	APRIL	MAY
Overall Constant		14.350	17.483	18.520	20.08
Crop Region 10 Constant		1.379	- 3.062	-4.04	-4.99
September to March total Prec. (mm)	DFN	------	0.009	0.008	0.014
November to March average Temp. (°C)	DFN	------	1.569	1.636	1.571
November to March average Temp. (°C)	SDFN	------	- 0.164	-0.162	-0.230
April Temp (°C)	DFN	------	-------	0.315	0.684
April Temp (°C)	SDFN	------	-------	-0.092	-0.151
May Prec. - P.E.T. (mm)	DFN	------	-------	------	0.079
May Prec. - P.E.T. (mm)	SDFN	------	-------	------	-0.0012
Standard Error (cent/hect)		4.32	3.33	3.34	2.54
R^2		-----	0.49	0.53	0.75
Adjusted R^2		-----	0.40	0.39	0.65

Standard Deviation of Yields = 4.29 cent/hect

DFN = Departure from Normal
SDFN = Squared Departure from Normal
*No trend is assumed.

REVISED 31 DECEMBER 1975

WINTER WHEAT BLACK SOIL ZONE COVARIANCE MODEL

Region: Crop Region 11 (West), Crop Region 12 (East)
Years: 1958-1971
Trend Variables: 1958=1, 1959=2, ..., 1971=14.
No variable for region.
Thornthwaite's method was used for P.E.T., A=1.032, I=33.508.
Daylength correction factor is for 51°N latitude.
Area constant: Region 11=0, Region 12=1.

Variable		Normal	Trend	February	March	April	May
Constant			12.6252	9.5726	10.4461	11.2046	10.8670
Trend			0.4804	0.7743	0.6778	0.6259	0.6700
Area Constant			0.6572	2.0700	1.8556	2.0569	2.0032
Jan-Feb Avg Temp (°C)	DFN	- 8.22		0.9915	0.6978	0.4165	0.4363
Mar Temp (°C)	DFN	- 3.14			0.4263	0.7688	0.6821
Apr Prec (mm)	DFN	35.10				0.0293	0.0332
	SDFN					*0.0023	*0.0021
Apr Temp (°C)	SDFN	6.60				-0.2049	-0.1873
May Prec.-P.E.T. (mm), C=1.29	DFN	-43.19					0.0237
Se			3.82	2.82	2.75	2.42	2.34
R^2			0.23	0.60	0.63	0.75	0.78
R^2 (Adjusted)			0.17	0.55	0.57	0.66	0.69

Standard Deviation of Yields = 4.19

DFN is Deviation from Normal
SDFN is Squared Deviation from Normal
*Note squared coefficient is positive, data should be censored for estimation, $|DFN| \leq 3.67$ 2.5 x (Standard deviation of variable).

REVISED

CENTRAL DISTRICT WINTER WHEAT COVARIANCE MODEL

Region: Crop Region 13
Data Base: 1958-73
Normals are based on the entire time period.
Yield data are measured in centners per hectare.
Potential Evapotranspiration is estimated using Thornthwaite's method (A = 0.942, I = 27,580).
Average monthly daylength is for latitude 56°N (Daylength factor: May = 1.39).

Variable	Coding
Overall Constant	=1
Linear Trend, 1958-73	1958=1, 1959=2, ..., 1973=16
December to March average Temp (°C)	Departure from Normal (Normal = -7.5°C)
April Temp (°C)	Departure from Normal (Normal = 5.3°C)
May Prec. - P.E.T. (mm)	Departure from Normal (Normal = -38.2 mm)

TRUNCATED MODELS FOR CENTRAL DISTRICT WINTER WHEAT (1958-73)

Variable		Trend	Truncation Time March	April	May
Overall Constant		7.01	6.66	7.49	8.09
Linear Trend, 1958-73		0.652	0.693	0.674	0.624
Dec to Mar Temp (°C)	DFN	----	0.450	0.444	0.351
Apr Temp (°C)	DFN	----	------	-0.192	-0.242
May Prec. -P.E.T. (mm)	DFN	----	------	-----	0.0331
Standard Error (cent/hect)		2.06	1.85	1.65	1.55
R^2		0.71	0.78	0.84	0.87
Adjusted R^2		0.69	0.75	0.80	0.82

Standard Deviation of Yields = 3.69 cent/hect

DFN = Departure from Normal

Revised 1/16/76

VOLGA-VYATSK WINTER WHEAT MODEL - REGION 14

Region: Crop Region 14
Data Base: 1958-73
Normals are based on the time period 1958-73.
Yields and climatic data are for Region 14 only.
Yield data are measured in centners per hectare.
Potential evaporation is estimated using Thornthwaite's method (A=0.920, I=26.14).
Average monthly daylength is for latitude 56° (May = 1.39, June = 1.47).

Variable	Coding
Overall Constant	=1
Linear Trend	1958=1, 1959=2, ..., 1973=16
April Temp ($^{\circ}$C)	Departure from Normal (Normal=3.8°C)
	Squared Departure from Normal
May Prec - P.E.T. (mm)	Departure from Normal (Normal=-41.4 mm)
June Prec - P.E.T. (mm)	Departure from Normal (Normal=-57.7 mm)
	Squared Departure from Normal

Revised 1/16/76

TRUNCATED MODELS FOR VOLGA-VYATSK WINTER WHEAT (1958-73) - Region 14

Variable		Trend	April	May	June
		Coefficients for Truncated Models			
Overall Constant		8.670	9.876	10.373	10.931
Linear Trend 1958-73		0.405	0.433	0.322	0.260
April Temp (°C)	DFN	-----	0.185	0.362	0.510
	SDFN	-----	-0.278	- 0.192	- 0.018
May Prec - P.E.T. (mm)	DFN	-----	-----	0.055	0.068
June Prec - P.E.T.	DFN	-----	-----	-----	0.065
	SDFN	-----	-----	-----	- 0.0012
Standard Error (cent/hect)		2.67	2.34	1.98	1.67
R^2		0.36	0.50	0.72	0.84
Adjusted R^2		0.31	0.48	0.62	0.73

Standard Deviation of Yield = 3.22

DFN = Departure from Normal
SDFN = Squared Departure from Normal

Revised 1/29/76

UPPER VOLGA WINTER WHEAT MODEL REGION 15

Region: Crop Region 15
Data Base: 1958-71
Normals are based on the period 1958-71.
Yield data are measured in centners per hectare.
Potential evapotranspiration is estimated using Thornthwaite's method (A = 0.979, I = 30.001).
Average monthly daylength is for latitude 58°N (Daylength factor May = 1.34; June = 1.41).

Variable	Coding
Overall Constant	1
Linear Trend 1958-71	1958=1, 1959=2, ..., 1969=12, 1970=12, 1971=12
April Temp (°C)	Departure from Normal (Normal = 3.8°C)
	Squared Departure from Normal
June Prec. - P.E.T. (mm)	Departure from Normal (Normal = -65.8 mm)

Revised 1/29/76

TRUNCATED MODEL FOR UPPER VOLGA WINTER WHEAT (1958-71)

Region 15

Variable		Trend	April	June
		Truncation Time		
Overall Constant		8.772	10.256	10.50
Linear Trend 1958-71		0.613	0.644	0.657
April Temp (°C)	DFN		0.344	0.333
	SDFN		-0.394	-0.389
June Prec. - P.E.T. (mm)	DFN			0.0458
Standard Error (cent/hect)		2.81	2.09	1.78
R^2		0.47	0.76	0.85
Adjusted R^2		0.43	0.69	0.77

Standard Deviation of Yield = 3.72 centners/hectare

DFN = Departure from Normal
SDFN = Squared Departure from Normal

Revised 1/29/76

MIDDLE VOLGA WINTER WHEAT MODEL - REGION 16

Region: Crop Region 16 (Middle Volga)
Data Base: 1958-71
Normals are based on the 1958-71 period.
Yield data is measured in centners per hectare.
Potential Evapotranspiration is estimated with Thornthwaite's method (A = 1.065, I = 35.756).
Average monthly daylength is for latitude 52^{o}N: May = 1.32.

Variable	Coding
Overall Constant	=1
April Temperature (^{o}C)	Departure from Normal (Normal = 6.4^{o}C)
	Squared Departure from Normal
May Prec. - P.E.T. (mm)	Departure from Normal (Normal = -61.6 mm)

Revised 1/29/76

TRUNCATED MODELS FOR MIDDLE VOLGA - REGION 16

Variable		Truncation Time: April	Truncation Time: May
Overall Constant		16.39	16.66
Apr Temp (°C)	DFN	0.820	1.55
	SDFN	-0.395	-0.469
May Prec. - P.E.T. (mm)	DFN		0.162
Standard Error (cent/hect)		3.98	2.22
R^2		0.33	0.81
Adjusted R^2		0.21	0.75

Standard Deviation of Yields = 4.49

DFN = Departure from Normal
SDFN = Squared Departure from Normal

REVISED

NORTHWEST URALS WINTER WHEAT MODEL

Region: Crop Region 18 (Northwest Urals).
Data Base: Yield Data 1958-69; Climatic Data 1958-73.
Climatic normals are based on 1958-73 period.
Yields and climatic data are fro Crop Region 18 only.
Yield data are measured in centners per hectare.
Potential evapotranspiration is estimated using Thormthwaite's method (I = 23.536, A = 0.880).
Average monthly daylength is for latitude 58°N (May = 1.42, July =1.49, June = 1.53).

Variable	Coding
Overall Constant	=1
December through March Temp (°C)	Departure from Normal (Normal = -11.7°C)
	Squared Departure from Normal
April Temp (°C)	Departure from Normal (Normal = 2.9°C)
May Prec. - P.E.T. (mm)	Departure from Normal (Normal = -46.3 mm)
June Prec. - P.E.T. (mm)	Departure from Normal (Normal = -65.7 mm)
	Squared Departure from Normal
July Prec. - P.E.T. (mm)	Departure from Normal (Normal = -66.2 mm)

TRUNCATED MODELS FOR NORTHWEST URALS WINTER WHEAT

Variable		Truncation Time: March	April	May	June	July
Overall Constant		11.600	12.300	11.800	12.000	11.4000
Dec thru Mar Temp (°C)	DFN	0.035	0.177	0.230	0.276	0.241
	SDFN	-0.196	-0.323	-0.189	-0.164	-0.087
Apr Temp (°C)	DFN		0.579	0.730	0.787	1.01
May Prec. - P.E.T. (mm)	DFN			0.046	0.051	0.078
Jun Prec. - P.E.T. (mm)	DFN				0.0010	0.0046
	SDFN				-0.00036	-0.00084
Jul Prec. - P.E.T. (mm)	DFN					-0.031
Standard Error		1.86	1.61	0.96	1.04	0.71
R^2		0.31	0.55	0.86	0.88	0.96
Adjusted R^2		0.15	0.39	0.78	0.74	0.88

Standard Deviation of Yield = 2.06

DFN = Departure from Normal
SDFN = Squared Departure from Normal

REVISED 31 DECEMBER 1975

SPRING WHEAT BLACK SOIL ZONE MODEL

Region: Crop Region 11 (West), Crop Region 12 (East)
Years: 1958-1971
Trend Variable: 1958=1, 1959=2, ..., 1971=14.
No variable for region.
Thornthwaite's method was used for P.E.T., A=1.032, I=33.508.
Daylength correction factor is for 51°N latitude.

Variable		Normal	Trend	February	April	May	June	July
			Coefficients for Truncated Model					
Constant			6.9527	7.5573	7.9654	9.4034	7.5139	6.8663
Trend			0.8001	0.7244	0.6714	0.6502	0.7536	0.8368
Jan-Feb Avg Temp (°C)	DFN	-8.22		-0.2555	-0.3292	-0.5154	-0.5260	-0.6273
Apr Temp (°C)	DFN	6.60			0.2793	0.2416	0.3664	0.3519
May Prec (mm)	DFN	47.19				0.0680	0.0625	0.0875
	SDFN					-0.0026	-0.0018	-0.0020
Jun Prec-P.E.T. (mm), C=1.38	DFN	-64.48					0.0106	0.0103
	SDFN						*0.0007	*0.0008
Jul Prec-P.E.T. (mm), C=1.29	DFN	-70.58						-0.0245
Se			2.31	2.25	2.22	1.74	1.50	1.43
R^2			0.68	0.71	0.73	0.84	0.90	0.91
R^2 (Adjusted)			0.66	0.68	0.69	0.81	0.86	0.87

Standard Deviation of Yields = 3.99

DFN is Departure from Normal
SDFN is Squared Departure from Normal
*For estimation the June Prec-P.E.T. DFN should be censored because of positive coefficient on squared term, $|DFN|<84\simeq2.5$ X Standard Deviation of (June Prec-P.E.T. DFN).

REVISED

CENTRAL DISTRICT SPRING WHEAT MODEL - REGION 13

Region: Crop Region 13
Data Base: 1958-73
Normals are based on the entire time period.
Yield data are measured in centners per hectare.

Variable	Coding
Overall Constant	=1
Linear Trend, 1958-73	1958=1, 1959=2, ..., 1973=16
April Temp (^{o}C)	Departure from Normal (Normal = 5.3^{o}C)
	Squared Departure from Normal
June Prec (mm)	Departure from Normal (Normal = 62.9 mm)
	Squared Departure from Normal
August Prec (mm)	Departure from Normal (Normal = 62.99)
	Squared Departure from Normal

TRUNCATED MODELS FOR CENTRAL DISTRICT SPRING WHEAT (1958-73)

Variable		Trend	Truncation Time April	June	August
Constant		4.392	5.184	5.762	5.500
Linear Trend, 1958-73		0.745	0.727	0.690	0.803
April Temp (°C)	DFN	-----	-0.0494	0.094	0.0223
	SDFN	-----	-0.1841	-0.134	-0.132
June Prec (mm)	DFN	-----	-----	0.030	0.0267
	SDFN	-----	-----	-0.00074	-0.00076
August Prec (mm)	DFN	-----	-----	-----	0.C475
	SDFN	-----	-----	-----	-0.0018
Standard Error (cent/hect)		2.16	2.12	2.17	1.89
R^2		0.74	0.79	0.81	0.89
Adjusted R^2		0.72	0.73	0.72	0.79

Standard Deviation of Yields = 4.11 cent/hect

DFN = Departure from Normal
SDFN = Squared Departure from Normal

Revised 1/16/76

VOLGA-VYATSK SPRING WHEAT MODEL

Region: Crop Region 14
Data Base: 1958-73
Normals are based on the time period 1958-73.
Yields and climatic data are for Region 14 only.
Yield data are measured in centners per hectare.
Potential evaporation is estimated using Thornthwaite's method (A=0.920, I=26.14).
Average monthly daylength is for latitude 56°N (May=1.39, June=1.47).

Variable	Coding
Overall Constant	=1
Linear Trend	1958=1, 1959=2, ..., 1973=16
September through April total Prec (mm)	Departure from Normal (Normal = 317.5 mm)
May Prec - P.E.T. (mm)	Departure from Normal (Normal = -41.4 mm)
	Squared Departure from Normal
June Prec - P.E.T. (mm)	Departure from Normal (Normal = -57.7 mm)
	Squared Departure from Normal

Revised 1/16/76

TRUNCATED MODELS FOR VOLGA-VYATSK SPRING WHEAT (1958-73)

Region 14

Variable		Trend	Truncation Time: April	May	June
Overall Constant		4.792	2.699	3.683	4.051
Linear Trend 1958-73		0.615	0.862	0.826	0.799
Sep thru Apr total Prec (mm)	DFN	-----	-0.0251	-0.0268	-0.0207
May Prec - P.E.T. (mm)	DFN	-----	-----	0.0260	0.0233
	SDFN	-----	-----	-0.00115	-0.0012
Jun Prec - P.E.T. (mm)	DFN	-----	-----	-------	0.0245
	SDFN	-----	-----	-------	-0.000134
Standard Error (cent/hect)		2.29	2.13	1.93	2.02
R^2		0.64	0.71	0.80	0.82
Adjusted R^2		0.61	0.66	0.72	0.70

Standard Deviation of Yield = 3.67

DFN = Departure from Normal
SDFN = Squared Departure from Normal

Upper Volga Spring Wheat Covariance Model

Region: Crop Region 15
Data Base: 1958-71
Normals are based on the entire time period.
Yield data is measured in centners per hectare.
Potential Evapotranspiration (P.E.T.) is estimated using Thornthwaite's method (A=.97885, I=30.00156).
Average monthly daylength is latitude 54°N (Daylength factor: July (1.43)).

Variable	Coding
Constant	=1
September to April total prec (mm)	Departure from Normal (Normal = 283.19 mm)
July prec - P.E.T. (mm)	Departure from Normal (Normal = -86.04)
	Squared Departure from Normal

Truncated Models for Upper Volga Spring Wheat (1958-71)

Variable		Truncation Time		
		Trend	April	July
Constant		7.342	5.427	6.439
Linear Trend		.675	.931	.737
September to April total prec (mm)	DFN		-.025	-.022
July prec - P.E.T. (mm)	DFN			-.053
	SDFN			-.001
Standard Error (cent/hect)		1.91	1.51	1.18
R^2		.70	.83	.91
Adjusted R^2		.68	.80	.88

Standard Deviation of Yields = 3.37 cent/hect

DFN = Departure from Normal
SDFN = Squared Departure from Normal

Middle Volga Spring Wheat Covariance Model

Region: Crop Region 16 (Middle Volga).
Data Base: 1958-71
Normals are based on the entire time period.
Yield data is measured in centners per hectare.
Potential Evapotranspiration (P.E.T.) is measured using Thornthwaite's method (A=1.06542, I=35.75610).
Average monthly daylength is for latitude 52°N (daylength factors: June (1.39), July (1.37),

Variable	Coding
Overall Constant	=1
September to April total prec. (mm)	Departure from Normal (Normal = 270.06 mm)
June prec. - P.E.T. (mm)	Departure from Normal (Normal = -77.48 mm)
July prec. - P.E.T. (mm)	Departure from Normal (Normal = -97.08 mm)

Truncated Models for Middle Volga Spring Wheat

Variable		Constant Trend	Truncation Time: April	June	July
Overall Constant		9.83	9.829	9.829	9.829
September to April Prec. (mm)	DFN		.024	.023	.020
June Prec. - P.E.T. (mm)	DFN			.056	.051
July Prec. - P.E.T. (mm)	DFN				.024
Standard Error (cent/hect)		2.425	1.894	1.620	1.542
R^2		-----	.437	.623	.689
Adjusted R^2		-----	.391	.554	.596

Standard Deviation of Yield = 2.42

DFN = Departure From Normal

Revised 1/16/76

CAUCASUS - VOLGA SPRING WHEAT MODEL

Region: Crop Region 10 (Northeastern Caucasus) and Crop Region 17 (Lower Volga).
Data Base: 1958-72
Normals are based on entire time period.
Yield and climatic data are pooled over Crop Regions 10 and 17.
Yield data is measured in centners per hectare.
Potential Evapotranspiration is estimated using Thornthwaite's method (A=1.183, I=43.565).
Average monthly daylength is for latitude 48^{o}N (daylength factor May = 1.31, July = 1.31).

Variable	Coding
Overall Constant	=1
September to April Prec (mm)	Departure from Normal (Normal = 261.1 mm)
	Squared Departure from Normal
April Temp (^{o}C)	Departure from Normal (Normal = 9.5^{o}C)
May Prec. - P.E.T. (mm)	Departure from Normal (Normal = -59.7 mm)
	Squared Departure from Normal
June Prec (mm)	Departure from Normal (Normal = 46.4 mm)
July Prec - P.E.T. (mm)	Departure from Normal (Normal = -117.8 mm)
	Squared Departure from Normal

Revised 1/16/76

TRUNCATED MODELS FOR CAUCASUS - VOLGA SPRING WHEAT (1958-72)

Regions 10 and 17

Variable		Truncation Time: April	May	June	July
Overall Constant		8.719	8.941	8.738	9.102
Sep to Apr Prec (mm)	DFN	0.0142	0.0190	0.0277	0.0292
	SDFN	0.00015	0.00020	0.00029	0.00043
Apr Temp (°C)	DFN	0.281	0.299	0.320	0.324
May Prec - P.E.T. (mm)	DFN		0.0773	0.0918	0.0878
	SDFN		-0.00052	-0.00070	-0.00043
Jun Prec (mm)	DFN			-0.0464	-0.0568
Jul Prec - P.E.T. (mm)	DFN				0.0288
	SDFN				-0.0018
Standard Error (cent/hect)		3.26	2.56	2.52	2.32
R^2		0.17	0.52	0.56	0.66
Adjusted R^2		0.07	0.42	0.44	0.53

Standard Deviation of Yields = 3.38 cent/hect

DFN = Departure from Normal
SDFN = Squared Departure from Normal

NORTHWEST URALS SPRING WHEAT MODEL

Region: Crop Region 18
Data Base: 1958-73
Normals are based on the time period 1958-73.
Yields and climatic data are for Region 18 only.
Yield data are measured in centners per hectare.
Potential evapotranspiration is estimated using Thornthwaite's method (I=23.536, A=0.880).
Average monthly daylength is for latitude 58°N (April = 1.21, May = 1.42, June = 1.53).

Variable	Coding
Overall Constant	=1
Linear Trend, 1958-73	1958 = 1, 1959 = 2, ..., 1973 = 16
April Prec - P.E.T. (mm)	Departure from Normal (Normal = 8.3 mm)
April Temp (°C)	Departure from Normal (Normal = 2.9°C)
May Prec - P.E.T. (mm)	Departure from Normal (Normal = -46.3 mm)
June Prec - P.E.T. (mm)	Departure from Normal (Normal = -65.7 mm)
	Squared Departure from Normal

TRUNCATED MODELS FOR NORTHWEST URALS SPRING WHEAT (1958-73)

REGION 18

Variable	Trend	Truncation Time: April	May	June
Overall Constant	6.242	8.194	7.782	8.120
Linear Trend, 1958-73	0.275	0.045	0.094	0.098
Apr Prec - P.E.T. (DFN)	-----	0.096	0.093	0.065
Apr Temp (°C) (DFN)	-----	0.950	0.797	0.543
May Prec - P.E.T. (DFN)	-----	-----	-0.014	-0.026
Jun Prec - P.E.T. (DFN)	-----	-----	-----	0.042
(SDFN)	-----	-----	-----	-0.0004
Standard Error	2.02	1.74	1.78	1.49
R^2	0.31	0.56	0.58	0.76
Adjusted R^2	0.26	0.45	0.43	0.60

Standard Deviation of Yield = 2.35

DFN = Departure from Normal
SDFN = Squared Departure from Normal

Revised 13 July 1976

SOUTHERN URALS - WESTERN KAZAKHSTAN SPRING WHEAT COVARIANCE MODEL

Region: Crop Region 19 (S. Urals) and Crop Region 21 (W. Kazakhstan).
Yield Data Base: 1958-73 except missing for 1962-64, 1969-70 at W. Kazakhstan.
Meteorological normals are based on the time period 1958-73.
Yields and climatic data are pooled over Crop Region 19 and 21.
Yield data are measured in centners per hectare.
Potential evapotranspiration is estimated using Thornthwaite's method (I=36.768, A=1.081).
Average monthly daylength for Latitude 59°N (May=1.46, June=1.52).

Variable	Coding
Overall Constant	=1
Crop Region 21 Constant	=1 if data from Crop Region 21, otherwise = 0
November thru March Prec (mm)	Departure from Normal (Normal = 141.0 mm) Squared Departure from Normal
May Prec-P.E.T. (mm)	Departure from Normal (Normal = -77.165 mm)
June Prec-P.E.T. (mm)	Departure from Normal (Normal = -110.263 mm)
July Temp (°C)	Departure from Normal (Normal = 21.7 °C)

Revised 13 July 1976

TRUNCATED MODELS FOR SOUTHERN URALS - WESTERN KAZAKHSTAN SPRING - WHEAT

Regions 19 and 21 (1958-73)

Variable		Trend (Constant)	Truncation Time: March	May	June	July
Overall Constant		11.2	11.151	11.318	11.248	10.546
Crop Region 21 Constant		-4.40	-2.90	-3.213	-2.385	-1.775
Nov thru Mar Prec (mm)	DFN		0.039	0.0428	0.0198	0.0208
Nov thru Mar Prec (mm)	SDFN		-0.00028	-0.00031	-0.0005	-0.00029
May Prec-P.E.T. (mm)	DFN			-0.0142	-0.026	-0.0254
Jun Prec-P.E.T. (mm)	DFN				0.064	0.0435
Jul Temp (°C)	DFN					0.5918
Standard Error		3.26	2.96	3.02	2.72	2.58
R^2		0.31	0.48	0.49	0.61	0.66
Adjusted R^2		0.29	0.41	0.38	0.50	0.55

Standard Deviation of Yield = 3.85

DFN = Departure from Normal
SDFN = Squared Departure from Normal

NORTHEASTERN URALS SPRING WHEAT

Region: Crop Region 20.
Data Base: 1958-73.
Normals are based on the entire time period.
Yields and climatic data are for Region 20 only.
Yield data is measured in centners per hectare.
Potential evaporation is estimated using Thornthwaite's method (A=.906, I=25.20).
Average monthly daylength is for latitude 56°N (Daylength factor: June (1.46)).

VARIABLE	CODING
Overall Constant	=1
Linear Trend	1958=1, 1959=2, ..., 1973=16
April Prec. (mm)	Departure from Normal (Normal=23.5 mm)
June Prec. - P.E.T. (mm)	Departure from Normal (Normal=-63.8 mm)
August Prec. (mm)	Departure from Normal (Normal=55.9 mm)

TRUNCATED MODELS FOR NORTHEASTERN URAL SPRING WHEAT (1958-73)

VARIABLE		TRUNCATION TIME			
		TREND	APRIL	JUNE	AUGUST
Overall Constant		9.367	10.010	12.711	12.672
Linear Trend 1958-73		0.425	0.350	0.033	0.037
April prec (mm)	DFN		0.083	0.011	0.018
June prec - P.E.T. (mm)	DFN			0.089	0.108
August prec (mm)	DFN				-.056
Standard Error (cent/hect)		3.07	3.01	2.32	2.04
R^2		0.32	.39	.67	.76
Adjusted R^2		0.27	.30	.58	.68

Standard Deviation of Yields = 3.60 cent/hect

DFN = Departure from Normal

NORTHEAST KAZAKH SPRING WHEAT COVARIANCE MODEL

Regions: Crop Region 22 (Kunstanay), Crop Region 23 (Tselinograd), Crop Region 24 (Northern Kazakhastan) and Crop Region 25 (Pavlodar).
Data Base: 1958-1971 minus 1962-64 and 1969-70.
Normals are based on time period 1958-1971 for meteorological data.
Yields and climatic data are pooled over Crop Regions 22,23, 24 and 25.
Yield data are measured in centners per hectare.
Potential evapotranspiration is estimated using Thornthwaite's method (I=30.448, A=0.986).
Average monthly daylength is for latitude 53°N (May = 1.34, June = 1.44, July = 1.30).

Variable	Coding
Overall Constant	=1
Crop Region 24 Constant	= 1 if data from Crop Region 24, other regions = 0
April Temperature (°C)	Departure from Normal (Normal = 4.3°C)
May Prec-P.E.T. (mm)	Departure from Normal (Normal =-57.5mm)
June Prec-P.E.T. (mm)	Departure from Normal (Normal =-93.1 mm)
July Prec-P.E.T. (mm)	Squared Departure from Normal (Normal =-79.7mm)
July Temperature (°C)	Departure from Normal (Normal = 20.0°C)

TRUNCATED MODELS FOR NORTHEAST-KAZAKH SPRING WHEAT (1958-71)

REGIONS 22,23, 24, AND 25

Variable		Trend Constant	April	May	June	July
			Truncation Time			
Overall Constant		7.392	7.491	7.607	8.116	9.559
Crop Region 24 Constant		2.107	1.774	1.697	1.425	0.823
April Temperature (°C)	DFN	----	-0.454	-0.124	-0.236	-0.513
May Prec - P.E.T.	DFN	----	----	0.043	0.024	0.0200
June Prec -P.E.T.	DFN	____	____	____	0.077	0.075
July Prec - P.E.T.	SDFN	----	----	----	-----	-0.0013
July Temperature (°C)	DFN	----	----	----	-----	-0.432
Standard Error		2.87	2.74	2.56	2.19	1.71
R^2		0.10	0.20	0.32	0.52	0.73
Adjusted R^2		0.06	0.15	0.26	0.46	0.67

Standard Deviation of Yield = 2.98

DFN = Departure from Normal
SDFN = Squared Departure from Normal

SIBERIA - ALTAI SPRING WHEAT COVARIANCE MODEL

Region: Crop Region 26 (West Siberia) and Crop Region 27 (Altai Krai).
Data Base: 1958-72.
Yield and climatic are pooled over Crop Regions 26 and 27.
Normals are based on the entire time period.
Yield data is measured in centners per hectare.
Potential Evapotranspiration (P.E.T.) is estimated using Thornthwaite's method (A = 0.921, I = 26.224).
Average monthly daylength is for latitude 56° N (Daylength factors: May (1.40), June (1.46), July (1.47)).

VARIABLE	CODING
Overall Constant	=1
Crop Region 26 Constant	=1 if data from Crop Region 26
	=0 otherwise
September to March total Prec. (mm)	Departure from Normal (Normal=195.0 mm)
April Prec. (mm)	Departure from Normal (Normal=26.0 mm)
	Squared Departure from Normal
May Prec. - P.E.T. (mm)	Departure from Normal (Normal=-50.0 mm)
	Squared Departure from Normal
June Prec. - P.E.T. (mm)	Departure from Normal (Normal=-75.7 mm)
July Prec. - P.E.T. (mm)	Squared Departure from Normal (Normal=-82.3 mm)
August Prec. (mm)	Departure from Normal (Normal=53.8 mm)

TRUNCATED MODELS FOR SIBERIA-ALTAI SPRING WHEAT 1958-72

VARIABLE		TRUNCATION TIME *TREND	MARCH	APRIL	MAY	JUNE	JULY	AUGUST
Overall Constant		10.367	9.974	10.567	12.382	11.822	13.235	13.221
Crop Region 26 Constant		-0.520	0.265	0.092	-1.388	-1.391	-2.140	-1.906
September to March total Prec. (mm)	DFN	------	0.046	0.018	0.018	0.011	0.007	0.010
April Prec. (mm)	DFN	------	-----	0.183	0.104	0.079	0.047	0.077
	SDFN	------	-----	-0.00405	-0.00483	-0.00376	-0.00473	-0.00510
May Prec. - P.E.T. (mm)	DFN	------	-----	--------	0.055	0.039	0.046	0.055
	SDFN	------	-----	--------	-0.00116	-0.00065	-0.00077	-0.00056
June Prec. - P.E.T. (mm)	DFN	------	-----	--------	--------	0.052	0.061	0.064
July Prec. - P.E.T. (mm)	SDFN	------	-----	--------	--------	--------	-0.00062	-0.00080
August Prec. (mm)	DFN	------	-----	--------	--------	--------	--------	-0.062
Standard Error (cent/hect)		3.91	3.53	3.05	2.78	2.54	2.43	2.09
R^2		----	0.21	0.46	0.59	0.67	0.71	0.80
Adjusted R^2		----	0.16	0.37	0.48	0.56	0.60	0.71

Standard Deviation of Yields = 3.85 cent/hect

DFN = Departure from Normal
SDFN = Squared Departure from Normal
*No trend is assumed.

NASA-JSC