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(FOUO 1/79)

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TRANSLATIONS ON USSR AGRICULTURE

(FOUO 1/79)

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STATISTICAL ANALYSIS OF SOIL TENDENCY TO WIND EROSION

Moscow DOKLADY VASKhNIL in Russian No 6 Jun 78 pp 22-23

[Article by A. L. Andreychuk, Candidate of Agricultural Sciences; Ya. L. Bronshteyn, Candidate of Technical Sciences; and M. I. Rubinshteyn, Candidate of Agricultural Sciences (Presented on 5 May 77 by A. M. Mamytov, Corresponding Member of VASKhNIL]

[Text] The development of soil conservation measures requires knowledge of both the physical-mechanical properties of the soil and the statistical data characterizing the roughness of the soil surface and wind activity.

A full analysis of the degree to which soils yield to the forces of deflation must, in the general case, also take into account other factors affecting the erosion process--the presence of stubble, soil moisture, etc. Since the effect of most of them is stochastic in nature, the soil's tendency to wind erosion should be determined by means of a probability index taking into account the statistical parameters involved in the analysis of these factors. We will limit ourselves to an analysis of the basic ones--the roughness of the soil surface, calculated on the basis of data on the fractional composition of the soil, and wind speed. Then occurs a random event, the movement of a soil particle under the effect of the wind, with the presence in the soil of particles whose dimensions do not exceed a certain critical $2R_\Phi$, and the effect of the wind of a critical speed U_Φ. On the strength of the independence of events $(2R_\Phi)$ and (U), the probability of this event is equal to the product of the probabilities of the two random events indicated:

$$P(D)=P(2R\leqslant 2R_\Phi)P(U\geqslant U_\Phi).$$

Since the critical values lie within the limits of zero and a certain maximum, it is necessary to know the laws of distribution of R_Φ, U_Φ.

Statistical analysis of the results of fractional separation of soil samples (from the southern sierozem of the Kazakh SSR) indicated that the percent content of fractional masses with a probability greater than 0.5 is subject to the normal law of distribution:

$$f(r_м) = \frac{1}{0,933\sqrt{2\pi}} \exp \times \times \left[-\frac{(r_м - 0,621)^2}{2 \cdot 0,933^2} \right], \quad (1)$$

where $2r_м$ - the size of the particles.

The statistical picture of the distribution of wind speeds in the area from which the soil samples were taken was obtained on the basis of years of meteorological observations, data from which is presented in [1]. Our analysis showed that the hypothesis concerning the distribution of wind speeds does not contradict experimental data with a probability of $0,273 > 0,1$, which, according to the W-criterion [2], insures the required level of credibility. The wind speed probability density takes the form

$$f(U_ф) = \frac{1}{0,707\sqrt{2\pi}} \exp \times \times \left[-\frac{(U_ф - 3,14)^2}{2 \cdot 0,707^2} \right].$$

The theoretical-experimental study which the authors made of the erosion of the lightly-textured soils of the southern part of Kazakhstan made it possible to establish a relationship between the radius $R_ф$ of particles subject to deflation and a critical wind speed at the moment deflation begins:

$$R_ф = 0,0032 U_ф^2 = a U_ф^2.$$

In the foregoing expression, particle sizes are presented in the form of a determinate functional dependence on the random argument; therefore, the radius $R_ф$ is also a random variable. The density of distribution of the sizes is found in the form

$$g(r_ф) = \frac{1}{0,08\sqrt{2\pi}\sqrt{r_ф}} \exp \times \times \left[-\frac{(r_ф - 0,1765)^2}{2 \cdot 0,04^2} \right]. \quad (2)$$

As follows from analysis of the last expression, the distribution of the sizes of particles with a potential tendency to deflation varies from the normal.

Considering the deflation of particles as a random process which is the result of the interaction (intersection) of random variables $R_м$, the presence in the soil of particles of a certain size and $R_Ф$ -- the potential possibility of their movement under the effect of wind, we have a system of two random variables with a distribution function $F(R_м, R_Ф)$. The deflation of soil particles of a given size is a random event $r_д$, which occurs with the simultaneous realization of both conditions indicated above. On the strength of the independence of $R_м$ and $R_Ф$ the probability of the event $r_д$ is equal to

$$P(r_д) = P(r_м)\,P(r_Ф),$$

while the distribution density of the random variable $R_Ф$ is

$$f(r_д) = f(r_м)\,g(r_Ф), \qquad (3)$$

where $f(r_м)$, $g(r_Ф)$ are calculated in accordance with expressions (1) and (2) respectively.

The distribution function of the random variable $R_Ф$ characterizes the probability of the deflation of particles whose size is smaller than the given

$$F(r_д) = F(r_м)\,G(r_Ф).$$

The graphic solution of the foregoing equation, presented in the form of a nomogram, is shown in the figure. In the first quadrant are plotted the curves of distribution density $g(r_Ф)$ and the distribution function $G(r_Ф)$; in the third, the curves $f(r_м)$ and $F(r_м)$; in the second is constructed the set of curves $F_м G_Ф = c$, where $0 \leq c \leq 1$ is the levels of probability; while in the fourth quadrant is constructed the curve of critical wind speed as a function of particle size

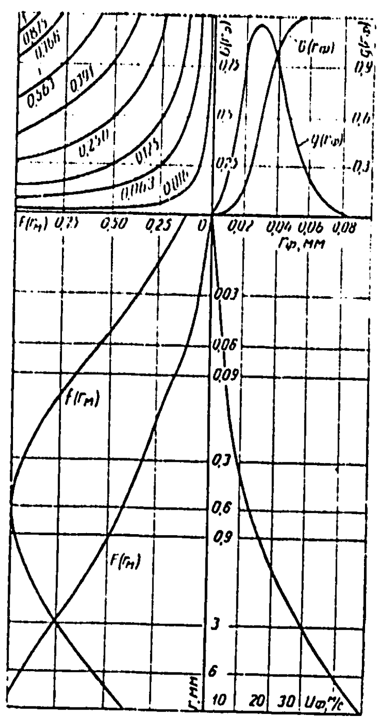
$$U_Ф = \sqrt{R/a} = 17{,}8\sqrt{R}, \quad м/с.$$

Thus, the statistical criterion--the estimate of the tendency of a particle with a radius $R_Ф$ to deflation by a wind of speed $U_Ф$ -- is equal to

$$c = F(r_м)\,G(r_Ф).$$

For example, for a soil whose surface layer is composed of particles of equivalent diameter $2R_м = 2$ мм we find in the fourth quadrant $r_ф = 0.04$ мм. Probabilities $F(r_м) = 0.6$ and $G(r_ф) = 0.82$. We find the value of the statistical criterion in the second quadrant as equal to 0.492. Thus, the probability of deflation of a mass of particles no more than 2 mm in size is equal to 49.2%.

Let us calculate, for example, the probability of deflation of a soil by a wind with a speed of 5 m/s. We plot the value of the speed on the lower horizontal axis of the fourth quadrant and, erecting a perpendicular, we find the point of intersection from the speed curve and the value corresponding to it $R_м = 0.09$ мм. Projecting it for $F(r_м)$ and $G(r_ф)$ we find in the second quadrant that the probability of deflation of the soil with a wind speed of 5 m/s is equal to 0.008 or 0.8%.



Nomogram of soil deflation probability.

We have solved the problem of establishing the statistical criterion for the degree to which a soil yields to deflation on the basis of a knowledge of the roughness of the soil surface and the distribution of wind speeds. The new method of determining the numerical characteristic of the deflation index is finding practical application.

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CAPILLARY METHOD OF LEACHING SALINE SOILS

Moscow DOKLADY VASKhNIL in Russian No 8, Aug 78 pp 37-39

[Article by S. V. Sanoyan, Candidate of Technical Sciences (Presented on 30 Mar 77 by S. V. Nerpin, Corresponding Member of VASKhNIL]

[Text] The new capillary method (which we call the "circulation" method) consists in the removal of excess salts by washing them out onto the soil surface and then washing them away with water. In order to carry out this leaching process, the ordinary furrows are cut 2.5 and 3.0 m from one another.

The water run into the furrow percolates into the soil and, as a result of intensive evaporation from the areas between the furrows, capillary forces begin to act on the surfaces of these areas. Generated under their effect are circulation currents moving from the furrows to the evaporating surface of the soil. These currents carry the salts out to the surface, from which they are periodically washed off and removed. With the existence of a good capillary network, the pressure gradient increase 10 times and more (in comparison with the pressure gradient with routine leaching against a drainage background) due to the development of capillary forces on the interfurrow areas.

The figure shows a diagram of circulation leaching. As can be seen from profiles of soil salts, these accumulate primarily in the upper 40-50-centimeter layer. The salts are more easily brought to the soil surface from the upper layer than moved in the opposite direction--deep toward the ground water surface. It should be noted that the circulation method of leaching frees the soil of salts and thereby removes the threat of its later resalinization.

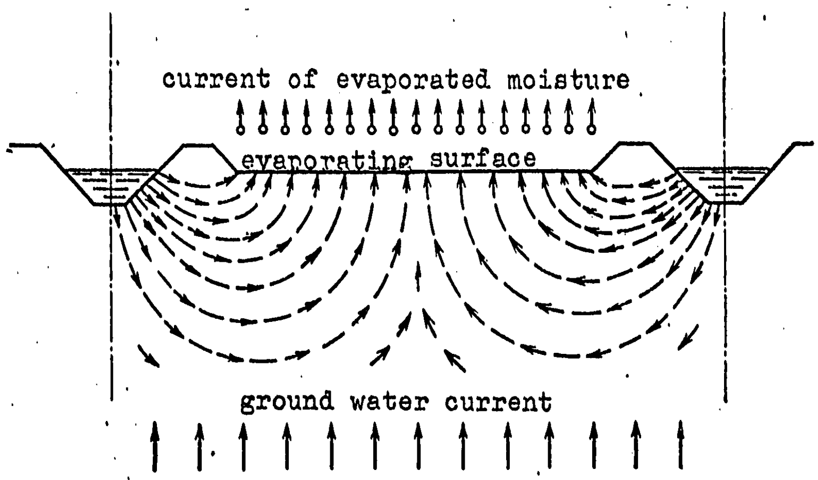

Diagram of water movement
with the
capillary method of leaching saline soils.

The degree of complexity of the theoretical justification of this leaching method depends on the type of equations we use to describe the currents of water q_w and the salts q_c. If we ignore electrical and heat fields, the currents q_w and q_c are described by the equations

$$\left.\begin{aligned} q_w &= a_{ww}X_w + a_{wc}X_c \\ q_c &= a_{cw}X_w + a_{cc}X_c \end{aligned}\right\} \qquad (1)$$

In addition to the salt flow, which consists of two components of the diffusion flow $a_{cc}X_c$ and the flow of the differential component of the concentration in the boundary layers $a_{cw}X_w$ (the mechanical-concentration effect), it is also necessary to take into consideration the convective transfer of the salts found within the entire interstitial space

$$q_{c(\text{кон})} = V \cdot C_{\Phi}, \qquad (2)$$

where V - rate of movement of the solution during filtration and C_{Φ} - the concentration of the filtrate. Then, taking into account the fact that $V = q_w$, the equation of salt transfer takes the form:

$$q_c = a_{cw}X_w + a_{cc}X_c + q_w C_{\Phi}. \qquad (3)$$

Let us analyze the role (1) of the individual components of the flows of moisture and salts as applied to the conditions of the circulation method of soil leaching.

On the basis of an analysis of experimental data, with a salt concentration gradient $X_c = 0{,}21\ \text{cm}^{-1}$ and a soil moisture content of 25% (of a mass of dry soil), the rate of osmotic capillary moisture flow was found to be equal to $3{,}85 \times 10^{-5}\ \text{cm} \cdot \text{s}^{-1}$. Taking into consideration the rectilinear profile of the rates with capillary osmosis, we can calculate this value for the case of complete saturation, multiplying it by the ratio of moisture contents of 25 and 37%. Then for saturated soils we will have $a_{wc}X_c \approx 5{,}7 \times 10^{-5}\ \text{cm} \cdot \text{s}^{-1}$.

In order to estimate the transfer of moisture in the course of circulation leaching we must multiply this value by the ratio of salt concentration gradients in the experiment and under field conditions. The calculation has been performed for an average line of flow. The length of the filtration path is 150 cm. The difference in concentration is calculated on the basis of the fact that the solution at the soil surface is saturated with salts, while the water in the furrow is practically fresh. The value of the concentration gradient in this instance is $6 \times 10^{-4}\ \text{cm}^{-1}$. The gradient in the experiment was $2{,}1 \times 10^{-1}$, the ratio of the gradients being 3×10^{-3}. Using this ratio, we find that with circulation leaching the rate of osmotic capillary water flow is $a_{wc}X_c = 5{,}7 \times 10^{-5} \times 3 \times 10^{-3} = 1{,}7 \times 10^{-7}$ cm·s^{-1}.

The value of the hydraulic flow $a_{ww}X_w$ is equal to the rate of evaporation. For the first stage of evaporation, that is, when the menisci dropped only in the capillaries with the largest dimensions, this rate had, depending on the season of the year, a value of from $0{,}76 \times 10^{-6}$ to $1{,}43 \times 10^{-6}$ cm·sec^{-1}. Thus, when osmotic capillary flow makes the greatest contribution, its relation to to the pressure flow is from 10 to 18%. When during the leaching process the concentration of the solution drops to 0.6 of saturation, the rate of evaporation increases correspondingly from $2{,}35 \times 10^{-6}$ to $4{,}42 \times 10^{-6}$ cm·sec^{-1}. In this case, the ratio of the osmotic capillary flow to the pressure flow is from 3.5 to 6.7%.

These calculations indicate that when in this case the filtration calculations are performed without taking into account the thermodynamic forces X_c, the error in the calculation of filtration flow is on the order of 10%. In order to reduce the error in the hydraulic calculation and, at the same time, to avoid the necessity of simultaneously solving the equations in (1), we may proceed as follows. Perform the hydromechanical calculation on the basis of the equation $q_w = a_{ww}X_w$; and then, after performing this calculation, make the appropriate correction in the value of the filtration rate taking into account the existence of forces X_c.

Let us now consider the relationship of the components making up the second equation in the system in (1).

A value for the coefficient of diffusion of the order of 10^{-6} $cm^2 \cdot s^{-1}$ has been obtained experimentally for soils of the type here under consideration. With an average value along the line of flow, the salt concentration gradient was 6 X 10^{-4} cm^{-1}. The diffusion flow rate was $a_{cc}X_c = 6 \times 10^{-10}$ $cm \cdot s^{-1}$. If we assume that the greatest gradient value may vary from the average by an order of one, in this case the rate of diffusion will be of the order 6 X 10^{-9} $cm \cdot s^{-1}$.

Let us move on to an estimate of the value $a_{cw}X_w$ with the following assumptions. The ion atmosphere profile is identical in the case of both model system and soils--the ion atmospheres in both systems do not overlap one another within the pores. Under these assumptions, the values of $a_{cw}X_w$ do not depend on the specific surface of the system and the results obtained for the model system may be extended to the actual soil. The value of $a_{cw}X_w$ for the model system may be obtained from the experiment. The change in the concentration produced by the flow $a_{cw}X_w$ is calculated in accordance with the following relationship

$$\Delta C = \frac{a_{cw}X_w}{V},$$

where V - rate of filtration. Therefore,

$$a_{cw}X_w = \Delta C \cdot V. \qquad (4)$$

According to experimental data, the value of ΔC is of the order of 5 X 10^{-2} g/l with a low concentration, which corresponds to the concentration in parts of a mass of water $\Delta C = 5 \times 10^{-5}$, the rate of filtration being equal to 5×10^{-3} cm/s. Then $a_{cw}X_w = 2{,}5 \times 10^{-7}$ cm/s^{-1}. Taking into account the ratio of the pressure gradients in the experiment and in nature, which is equal to 0.7, the value of $a_{cw}X_w$ in the case of circulation leaching will be equal to 1.75 X X 10^{-7} cm/s-1.

These assumptions regarding the applicability of experimental data obtained in model systems at low concentrations of solution apparently give a considerably higher estimate of the mechanico-concentration effect. In the case of a solution of high concentration, the ion atmospheres contract and all osmotic capillary effects are weakened. Electroösmosis, for example, disappears.

We may assume in this regard that the actual value of $a_{ck}X_w$ will be substantially lower than was obtained by using data from the model system.

In conclusion, let us calculate the rate of convective transfer. With a concentration of saturation of the solution $C \approx 0.25$ (in parts of a mass of solution) and a filtration rate equal to the rate of evaporation ($\approx 2\text{-}3 \times 10^{-6}$ cm/s^{-1}), the rate of convective transfer is $(0.5\text{-}0.75) \times 10^{-6}$ cm/s^{-1}.

These calculations make it possible to draw conclusions concerning the individual components of the equation of salt transfer. In describing the desalinization processes occuring during intensive leaching it is possible not to consider the diffusion transfer of salts.

In describing convective transfer it is to advantage to employ, not a relation in the form $q_c = a_{ck}X_w + VC_\Phi$, where C_Φ - salt concentration calculated using the water extract method, but rather the equation $q_{c(\text{conv})} = C_\Phi$, which takes into account not only the convective transfer of salts contained per part by volume of the pores (C_Φ), but also the convective transfer of the differential component of the concentration of salts $a_{ck}X_w$ passing near the surface of the particles.

This alternative greatly simplifies the calculation of convective salt transfer in the capillary method of leaching saline soils.

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BOOK ON CHERNOZEM SOILS IN VOLGA AND PRE-URALS REGIONS

Moscow CHERNOZEMY SSSR (POVOLZH'YE I PREDURAL'YE) [Chernozem Soils of the USSR (Volga and Pre-Urals Regions)] in Russian 1978 signed to press 4 Nov 78 pp 1-32, 293-297

[Annotation; table of contents, foreword, first chapter and conclusion from book produced at All-Union Order of Lenin Academy of Agricultural Sciences imeni V. I. Lenin and Order of the Red Banner of Labor Soil Institute imeni V. V. Dokuchayev, edited by Prof V. M. Fridland, Doctor V. A. Nosin, I. I. Lebedeva, R. A. Antipina, Z. P. Zubrilina, N. V. Surzheva, Izdatel'stvo "Kolos", 1,400 copies, 304 pages]

[Text] Annotation

This monograph on chernozem soils in the USSR (Volga and Pre-Urals regions) represents a review of literary and other materials concerned with chernozem soils found in the Bashkir ASSR, Mordovian ASSR, Tatar ASSR and in Gor'kovskaya, Kuybyshevskaya, Saratovskaya, Permskaya, Orenburgskaya and Ul'yanovskaya oblasts.

An exhaustive description is furnished in this book on the chemical and mineralogical structure, on the chemical, physical and water-physical properties and also on the principal agricultural-production indices of chernozem soils found in the Volga and Pre-Urals regions. The geography and genesis of the chernozem soils and also the structure of the soil cover of this naturally complicated region are examined in detail. The principal characteristics of the hydrothermal and nutritional regions of these soils are revealed.

The great volume of analytic data employed makes it possible to view the book as a source for specific information on soils.

Table of Contents

Foreword

Commencing with V.V. Dokuchayev and P.A. Kostychev, who 100 years ago investigated the chernozems found in the eastern portion of the Russian plain, these soils have been studied by many soil scientists, geographers and agronomists representing different scientific and production organizations; the vast amount of scientific-research, experimental-agronomic and production material contained in their works provides comprehensive descriptions for the diverse types of chernozem soils found in the forest-steppe and steppe areas of the Middle Volga and Pre-Urals regions. A considerable portion of the mentioned materials has already been published and is well known; the remaining portion is distributed among various institutes in the form of working materials.

One of the principal aims of this book is to describe the chernozem soils by large physical-geographic regions which, with only a few exceptions, are not linked to administrative boundaries. Thus, based upon a natural diversity, it will be possible to reveal clearly the more important genetic characteristics and regularities associated with the distribution of these soils. A great amount of attention was given to analyzing and describing the chernozem soils, their genesis, morphological structure and chemical and physical properties. The lower types of chernozem soils -- kinds, varieties and categories -- are discussed mainly from a comparative standpoint.

Materials are provided in some sections which describe the structure of the soil cover in the principal regions according to the water and thermal regimes, the agricultural-production grouping and the appraisal of the chernozem soils in the territory under review. They provide a genetic-systematic review and can serve as valuable scientific information during the course of solving important problems concerned with farming operations, the use of chemical processes and land reclamation work carried out on chernozem soils.

In addition to workers attached to the Soil Institute imeni V.V. Dokuchayev, scientific workers from the following organizations also participated in the preparation of this book: Gor'kiy, Saratov and Orenburg agricultural institutes, Institute of Biology of the Bashkir Branch of the USSR Academy of Sciences, Kazakh State University and leading specialists from the Volgogiprozem and Privolshgiprovodkhoz planning institutes. The organization and overall direction of the work were carried out by the Department of Genesis, Geography and classification of the Soil Institute imeni V.V. Dokuchayev and VASKhNIL.

Natural Conditions of Soil Formation and the Soil Cover of the Chernozem Zone in the Volga and Pre-Urals Regions.

The eastern portion of the chernozem zone of the European territory of the USSR, which embraces the middle Volga and western Pre-Urals regions (see Figure 1), is distinguished by diverse genetic forms for the chernozem soils found here, by substantial peculiarities in their composition and properties and by different dynamics for the processes and regime conditions occurring in these soils. The natural cause of the diverse nature of the chernozem soils is obvious: considerable broad-geographic and local variability in the soil formation factors for the vast and geologically complicated area under review.

The latter is a part of the Russian platform which adjoins the Ural mountain system in the east and which underwent a number of different age dislocations of various types. Quite often this is very clearly expressed in the geological structure and modern relief of a particular terrain.

In addition to the effect of complicated tectonics, the geological development of the territory proceeded along the path of intensive reorganization of the hydrographic network and transformation of the relief in connection with the repeated periods of galciation in the north, west and center of the Russian plain during the quaternary period, although these glaciations did not extend directly onto the given territory.

The peculiarities of the geological development of a territory are manifested in many objects of nature, including the soil cover and its formation.

Principal Features of Orography and the Geological Structure

The geological foundation of the territory consists of several large and deep-seated tectonic structures -- arched elevations and the basins that separate them, which are traced in a crystalling base and in the structure and thickness of the sedimentary rock and manifested in modern relief and hydrography.

In accordance with the data contained in the 11th Volume of "Geologii SSSR" [Geology of the USSR], the following large tectonic forms (from west to east, see Figure 1) are expressed within the boundaries of the territory under review.

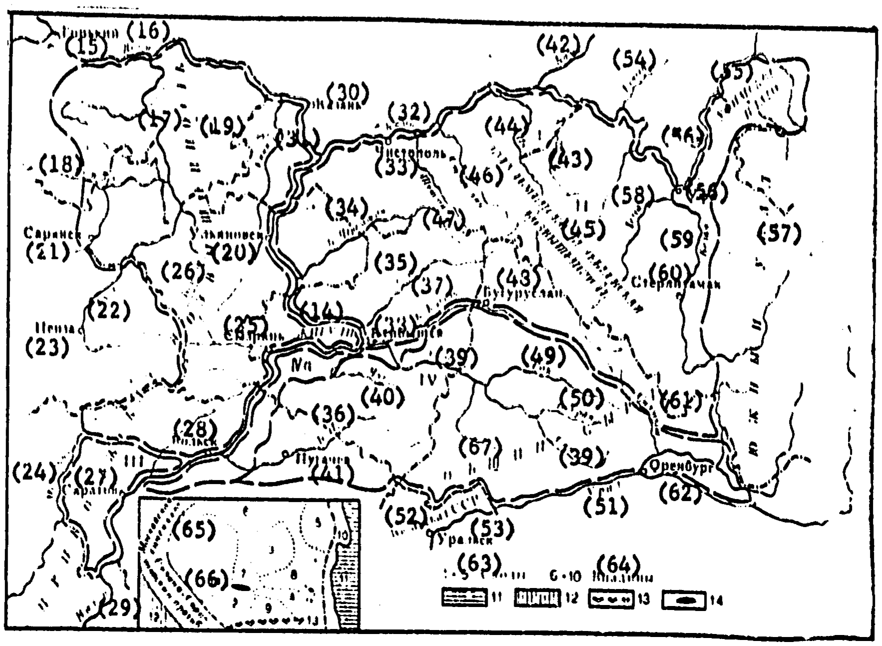

Figure 1. Diagram of natural-geographic regions and principal geotectonic structures in the Middle Volga and Pre-Urals regions

Key:

I. Pre-Volga forest-steppe
II. Forest steppe of Volga and Pre-Urals regions
III. Volga steppe region
IV. Volga and Pre-Urals steppe regions
IVa. Low (terrace) Volga steppe
Anticlines 1. Tokmovskiy
2. Zhigulevsko Pugachevskiy
3. Tatarskiy
4. Orenburgskiy
5. Bashkirskiy
Basins: 6. Kamskaya
7. Melekesskaya
8. SergiyevskoAbdulinskaya
9. Buzulukskaya
10. Predural'skiy downwarp
11. Western slopes of Ural Mountains
12. Voronezh anticline
13. Edge of Pre-Caspian syneclise
14. Zhiguli
15. Gor'kiy
16. Volga
17. Sura
18. Alatyr'
19. Pre-Volga Elevation
20. Ul'yanovsk
21. Saransk
22. Sura
23. Penza
24. Medveditsa
25. Syzran'
26. Barysh
27. Saratov
28. Vol'sk
29. Volga
30. Kazan'
31. Sviyaga
32. Kama
33. Chistopol'
34. Bol. Cheremshan
35. Sok
36. Bol. Irgiz
37. Bol. Kinel'
38. Kuybyshev
39. Samara
40. Chapayevsk

Key Cont.

41. Pugachev
42. Kama
43. Syun'
44. Ikh
45. Butul'minsko-Belebeyevskaya Elevation
46. Stepnoy Zoy
47. Sheshma
48. Buguruslan
49. Tok
50. Bol. Uram
51. Ural
52. Kazakh SSR
53. Ural'sk
54. Tanyp
55. Ufa Plateau
56. Ufa
57. Southern Urals
58. Dema
59. Belaya
60. Sterlitamak
61. Salmysh
62. Orenburg
63. 1-5 anticlines
64 6-10 basins
65. Moscow syneclise
66. Ryazano-Saratov downwarp
67. Obshchiy Syrt

Anticline elevations: Tokmovskiy, Zhigulevsko-Pugachev, Tatar, Bashkir, Orenburg.

Basins: Kamskaya, Melekesskaya, SergiyevskoAbdulinskaya, Buzulukskaya.

The elevations of the Middle Volga region in the west and southwest are separated from the Moscow syneclise and the Voronezh anticline by the Ryazano-Saratov downwarp; the east is distinguished by the regional pre-Urals downwarp, which proceeds parallel to the meriodional mountain structures of the Southern Urals.

In addition to the large tectonic forms, smaller structures are also found rather extensively -- swells, flexures, local elevations and so forth, the formation of which, in addition to the principal tectonic movements, is accompanied by veilings, erosions, slippages and various types of linear dislocations.

In accordance with the character of the principal peculiarities of the geological structure, the formation and the origin of the relief on the territory of the Middle Volga and Pre-Urals regions, several large portions are distinguished which appear as geo-morphological communities of a high taxonomic level.

The western portion of the territory under review, located on the right bank of the Volga River, applies almost fully to the Pre-Volga elevation (with the exception of the extreme southwestern sector, which lies in Saratovskaya Oblast beyond the watershed of the Medveditsa and Khoper rivers, which belongs to the High Don or Pre-Volga plain).

The Pre-Volga elevation appears as a raised plateau which stretches out strongly in a sub-meridional direction and which has an intricately separated and dense river and ravine-gully network.

Belonging on the whole to the zone of the vast Tokmovskiy tectonic anticline and its connected Zhiguli elevation, the Pre-Volga elevation, over an extended period of time and in several of its elements, has been subjected to local dislocations of various types and intensities, to the accumulation of precipitation under marine regime conditions and to repeated cycles of active continental denudation, erosion and the accumulation of deposits. As a result, the geological structure and relief in different parts of the Pre-Volga elevation are distinguished by their unique nature.

The northern part of the elevation, which does not exceed an absolute height of 200-250 meters, consists for the most part of upper Permian deposits of mainly the Tatar layer, with variegated (for the most part red) marlaceous clays stratified by platy limestones, dolomites and sandstones. In the southern direction the upper Permian deposits are covered by sandy-clay Juraisic and lower chalky deposits which often appear on the surface and yet which more often than not are covered by quaternary formations of a different genesis and considerable depth.

The middle portion of the Pre-Volga elevation, which lies to the south of the line connecting Saransk, Karsun and Ul'yanovsk and roughly up to the watershed for the upper reaches of the Uza (tributary of the Sura River), Medveditsa, Kadada and Tereshka rivers, is raised more: the high points of the plateau are located at an altitude of approximately 300 meters, with individual summits and outcroppings reaching 330-370 meters. The central position is occupied by a watershed terminal in the upper reaches; it diverts the principal rivers of the region (Sura, Barysh, Sviyaga and Syzrana) into various directions -- it is the huge bed-ridge plateau, the so-called Surskaya Shishka. With the exception of Samarskaya Luka, where thick carbonaceous and Permian limestones and dolomites are found, the middle area of the Pre-Volga elevation consists mainly of upper Cretaceous and higher Paleogenic deposits which form a lithologically complicated complex of compact and loose chalks, carbonaceous and non-carbonaceous rock -- glauconite and quartz sands and sandstones (mainly the Syzran' suite of the Peleogenic period). Here the quaternary cover formations often appear as shallow eluvium-deluvium local rock.

The southern portion of the Pre-Volga elevation, which narrows down considerably towards the south from Petrovsk and Vol'sk and beyond the Carpathian Mountains and which takes on the form of the tall and very strongly dispersed Volgo-Medveditsa Ridge in the Pre-Volga strip, is characterized by a predominance of lower and upper chalk deposits, including white chalky hills with local manifestations of upper and middle Jurassic deposits. Paleogenic deposits predominate in the area lying more to the west of the Volga River. These deposits contain a large number of sandstone areas, sandy non-calcareous opoki and lamellated-sandy layers of the upper Saratov suite (Eocene epoch).

The modern relief of the Pre-Volga elevation, which is not subject to cover freezing (perhaps with the exception of individual sectors along the northwest edge), developed during the quaternary period with the principal features of ancient orography being retained under the influence of intensive denudation of high surfaces, the formation of deluvium covers on the slopes and silt deposits in the river valleys. The predominant forms of relief were low ridge inter-ravine watersheds having narrow plateau summits and steep slopes. In some watershed areas and along the edges of river valleys, the relief becomes ridge-hilly; one also encounters individual flat-summit "tabular" outcroppings of former and higher surface levels. Moreover, the altitude amplitudes are quite often considerably, up to 150-200 meters. In addition, there are also slightly undulating plain areas which are usually linked to the valleys of the principal rivers.

The western and Pre-Volga portion of the Russian platform under review is relatively elevated and broken up; the eastern edge of this territory, which adjoins the Urals directly, is raised and broken up to an even greater degree.

The Ufa Plateau is located to the northeast of the city of Ufa. It extends to the Karatau Mountains and it has an absolute altitude of 300-450 meters, with individual peaks ranging to 500 meters. The plateau appears as a broad fold asymmetrical in structure having a steep western and an even more steep eastern slope; it consists of a deep thickness of limestones, marls, dolomites, gypsums, sandstones and calcareous clays of the upper Carboniferous Period -- lower Permian Period and penetrated by a network of deep canyon-forming valleys with native rock found on the slopes. Tertiary weathering crusts are found on the territory of the plateau above the compact rock of the Paleozoic Period. The quaternary eluvial and eluvium-deluvium surface formations have a slight depth and quite often consist of pebbles or crushed stone.

To the south of the Sima River Estuary, along the right bank of the Belaya River and along its meridional flow, stretches the Pribel'skaya piedmont ridge strip, which connects up to the leading ridges of the Southern Urals -- Takty-Arka, Bash-Altau and others -- in the east. The absolute height of the ridge peaks in this strip ranges from 300-350 meters, with even greater heights in some areas; the ridges decrease to a height of 250-200 meters in the west; here smooth and steeply undulating forms predominate which merge with a complex of inclined and weakly undulating denudation-accumulative terraces of the ancient Belaya River Valley. The ridges consist of Permian limestones, sandstones, marls, conglomerates and so forth, unmaintained Mesozoic continental deposits; closer to the Belaya River Valley the native rock is covered by thicknesses of loose quaternary deposits and surface covers of eluvium-deluvium formations.

The orographic regions cited above serve to outline the more elevated eastern edge of the Pre-Urals region.

To the west of the Belaya River and at a considerable distance from it, there is an isolated and raised region -- the Bugul'minsko-Belebeyevskaya Elevation which is connected to the large and deep tectonic structure -- the Tatar crystalline anticline. This vast plateau with high markings of 380-400 meters serves as an important watershed terminal for drawing together the headwaters of a number of large tributaries of the Belaya, Kama and Volga rivers. This river network, on the basis of a system of numerous small tributaries, thoroughly breaks up the area of the Bugul'minsko-Beleyevskaya Elevation into individual interfluvial areas, which at times resemble the ridges of flat-top hills ranging 150-180 meters in height above the surrounding terrain.

The elevation is made up of sandstones, fine-mica calcareous clays, platy dolomites and limestones, marls with gypsum layers and conglomerates (upper Permian, Kazan' layer); higher they are covered by a variegated complex of deposits of the Tatar Permian layer. Owing to a differing stability level with regard to denudation of the Kazan' and Tatar deposits, a typical terracing of the high elements of relief occurs and this is expressed mainly on slopes of southern exposure (southwest and southeast). On the whole, the relief of the Bugul'minsko-Belebeyevskaya Elevation is formed under the influence of prolonged and intensive denudation and under the conditions of a continental regime and positive epeirogenic movements. In this regard the young surface deposits in watershed areas are shallow; they are deeper only on the steep slopes of asymmetric profile ridges and on the terraces of river valleys.

In the northeastern and northern directions the Bugul'minsko-Belebeyevskaya Elevation changes into the Bel'sko-Kamskaya ridge plain, which gradually drops down to the Belaya and Kama river valleys, from 280-250 to 120-100 meters of absolute height (and lower along old river terraces). The changing of the elevation into this plain is expressed in a number of areas by clearly denuded spurs based upon a network of large lakes (Kandry-Kul', Asly-Kul') and flat-bottom dry basins of former lakes of old Karst origin.

The developed hydrographic network forms ridge interfluvial areas having a predominance of steep slopes and slightly undulating watershed plains, where in some areas one finds residual outcroppings of ridges, protuberances and shikhans.

The principal forms of macro-relief in this region are formed by deposits of the Ufa layer of the Permian system, which consists of a red colored thickness of sandstones, marl clays, aleurolites with thin layers of sandy grey marls, platy limestones and with inclusions of gypsum lenses.

Upper Permian continental deposits predominate in the large interfluvial areas: Syun' - Ik, Ik - Zay and Zay - Sheshma rivers. These deposits consist mainly of red colored calcareous clays and sandstones with conglomerate members (Belebeyevskaya suite).

Tertiary continental deposits are found near the edges of the ancient hydrographic network in some areas. They are represented by sands and sandstones and by pebble-gravel, clay and loamy deposits of considerable depth and variable in terms of depth and extent.

To the west and south of the Bugul'minsko-Belebeyevskaya Elevation there is a vast and rather monotonous, from a geomorphological standpoint, area that was initially referred to as the Zavolzh'ye Permian Plateau* by L.I. Prasolov. In the north it is terminated by the ancient Kama River Valley, in the west -- by the headwaters of the Cheremshan River and the Kondurcha River Valley, which runs in a southerly direction, and subsequently by the left bank of the Volga River. The Samara River is the natural southern border of the Permian Plateau; the eastern border is only sketchily outlined by the headwaters of the right and large tributaries of the Samara, Large Uran and Small Uran rivers, which have their sources in the elevations of the Obshchiy Syrt.

Within the borders outlined, the territory can be described as a raised and strongly undulating plain that is "table-flat" in some areas and that is broken up to a considerable degree by large river valleys into a number of large interfluvial areas considered to be the principal orographic elements. A complicated network of small tributaries, ravines and dry valleys serves to break up the principal interfluvial areas into a system of secondary watershed ridges -- divides having asymmetrical slopes, the tops of which are disposed at nearby hypsometric levels, which testifies to their origin from one overall levelling surface.

The absolute heights in the eastern portion of the plateau, which merges with the Bugul'minsko-Belebeyevskaya Elevation, range from 280 to 300 meters and gradually decrease in a westerly direction to 180-160 meters.

That portion of the Zavolzh'ye region which lies to the west of the Permian Plateau and north of Samarskaya Luka is classified as being in the zone of the tectonic Melekess basin (see Figure 1), consisting of neogenic (pliocenic) and quaternary, mainly ancient alluvium Volga-Kama deposits. This territory is noted for its Cheremshano-Kondurchinskiy geo-morphological region and it is described as having a steeply-ridged relief, an absolute height of up to 150-180 meters in the east and gradually decreasing in the west and north, in the direction of the Volga and Kama rivers, where vast slightly inclining ancient river terraces are developed (two or three, in addition to the flood plain filled by the Kuybyshev Reservoir and also the low flooded terraces).

The high Zavolzh'ye region consists almost exclusively of upper Permian deposits (Kazan' and Tatar layers). The spread of the former is limited and associated with local tectonic elevations (headwaters of the Sok River, the region around Kuybyshev and others). The Kazan' layer consists of limestone and dolomite suites -- from compact and clean to earthen, strongly clayed and often with gypsum inclusions. In some areas the layer is represented by a clay phase consisting of a suite of red and greenish-grey clays, gypsum layers and pinkish-brown argillite.

The deposits of the Tatar layer predominate beyond any doubt and they serve as the principal relief forming material over large areas. The Tatar layer

* It is more correct to refer to it as the Kamsko-Samarskoye Plato of the High Zavolzh'ye region.

is extremely complicated in structure and it changes greatly as it spreads out. Red, violet and brown clays; grey, white and pink marls; red and grey sandstones, layers of platy limestones -- these different types of rock, by alternating repeatedly in stratification, form a variegated lithological complex, which at one time was referred to as "layer of variegated marls."

Over an extended period of time (since the end of the Jurassic period), the Permian plateau of the Zavolzh'ye region has retained its character of continental land. Thus, with the exception of rare deposits of Jurassic sandstones on the summits of some watershed ridges, there are no deposits, including Neogenic ones, in the geological structure of the territory, although water from the Akchagyl'skaya marine transgression has penetrated through to the depths of the Permian plateau along the large river valleys. The sediment from such water, in the form of brown and grey clays and sands, is being observed along the edges of the Kama Sok, Kinel' and Small Kinel' river valleys and along a number of other tributaries.

The continental regime was retained even during the quaternary period, at which time eluviums and deposits of deluvium clays and loams formed on the sloping and concave surfaces of the ancient relief and alluvial deposits accumulated in the river valleys.

The southeastern edge of the Bugul'minsko-Belebeyevskaya Elevation, which ends with 500 meter high ridges between the headwaters of the left bank tributaries of the Belaya and Sakmara rivers, merges with the ridge elevation of the Obshchiy Syrt, which curves to the west and which is the principal watershed between the Volga and Ural basins. Initially expressed in the form of a massive hilly ridge 300-500 meters in height, the Obshchiy Syrt breaks up into a number of branches as it stretches towards the west, with these branches serving as watersheds between the headwaters of the great rivers in the Zavolzh'ye region; these orographically isolated branches often acquire their own titles -- Siniy Syrt, Melovoy or Buzulukskiy, Syrt and others. The principal ridge of the Obshchiy Syrt is in the form of a steep hilly ridge and flat-summit spurs and shikhans; it stretches out towards the southwest and is gradually lost in the wide and low ridges of the Low Syrtovoye Zavolzh'ye.

In the eastern portion, the Obshchiy Syrt consists of a noticeably dislocated thickness of the Ufa Permian layer, represented by sandstones, dolomites, loose limestones and clay conglomerates with the pebbles of hard Ural rock. In the middle or Orenburg part there is a predominance of deposits of the higher layers of the upper Permian Period and to the west -- in the region of the Buzulukskiy Syrt -- variegated continental thicknesses of trias are found here extensively; lithologically, these are very similar to rock of the Tatar layer; in addition, non-continuous and small in area and depth Jurassic and low-cretaceous deposits of a sandy and pebble nature are observed on the higher levels of the relief.

To the south of the Samara River, which originates at the Obshchiy Syrt and empties into the Volga at Kuybyshev between the Obshchiy Syrt and the Volga, stretches out the Syrtovaya Plain of the Zavolzh'ye region. It is usually divided up into higher and lower parts by the Bol'shaya Irgiza River Valley. The principal orographic elements of both parts of the territory -- extended slightly convex ridges or divides, divided by a system of ravines and dales usually having an overall axis towards the valleys of the principal rivers -- tributaries of the Volga. The latter represent the second typical element of the orography: they are great, deeply cut into and they include a number of ancient terraces, developed in particular along the left banks, where they are gradually converted into syrt plains.

The assymetry of the slopes is clearly expressed in the structure of both the principal interfluvial areas and the secondary watersheds.

The watershed plateaus of the high syrt plain lie at levels on the order of 220 meters and the low syrt plain -- 130-80 meters. The high markings apply mainly to the eastern edge of the syrt plains and the lower ones -- to the western edge, where the syrts are replaced by vast and scarcely undulating Pre-Volga terraces.

The geological structure of the High Syrt Plain is based upon red-colored stratified sandy-clay and thin limestone-marl deposits of the upper Permian formation, with a large portion being concealed under late formations and appearing only in certain areas along the southern, steep and raised slopes of river valleys. Deposits of the middle and particularly the upper Jurassic formation appear in some areas of the eastern portion of the High Syrt Plain. These deposits cover the summits of large watersheds: they are represented by yellow clay sands having thin layers of iron and quartz sandstones, grey and black clays with layers of gypsum and inclusions of phosphorites and platy limestones. Small pockets of upper Jurassic deposits are often noted in the western portion of the syrt plain

A large gap is noted above the Jurassic sediments in the sequence of geological stratifications, right up to the Neogenic (its upper formation -- Pliocenic). The sediments of the latter fill the low areas of the ancient relief to a great depth and transgressively overlap its high elements. From the slopes of the Obshchiy Syrt towards the west, the depth of the Neogenic (Pliocenic) deposits increases, reaching a depth of more than 100 meters in the vicinity of the Volga aggradation terraces and thereafter spreading across the Volga valley.

The lower portion of the Pliocenic formation consists of a variable complex of fresh water, lake-swamp and alluvial laminated clay and sandy deposits; such was the valley of the Pra-Volga and its main tributaries during the Pre-Akchagyl' Period (Kinel' suite). The latter was covered by deposits of the upper Pliocenic formation, consisting of sediments of the marine Akchagyl' transgression, which were represented by grey-black, yellow-greenish and brown saline clays having thin layers and lenses of sands, sandy loam soils, weakly-cemented marls and shell rock.

The depth and composition of the Akchagyl deposits vary as a result of the odd coastal line of the marine transgression and the phase peculiarities of the sediment accumulation. Upwards the marine phase of the Akchagyl is replaced by a fresh water phase, with subsequent conversion of the latter over to the highest continental phase of the Pliocenic formation, represented by syrt clays. They play a most important role in the formation of modern relief on huge territories of the Syrt Zavozh'ye region, to the south of the Samara River and also to the north of Samarskaya Luka in the interfluvial area for the Kama - Cheremshan - Kondurcha - Volga rivers. The greatest depth for syrt clay is found on the steep northern slopes of large interfluvial areas; where there are high watersheds and narrow inter-summit ridges, the cover of such clays is considerably thicker. Thus there is every reason for believing that deluvial processes played the principal role in the formation of the syrt clays.

The western edge of the Syrt Zavolzh'ye region forms a broad strip of ancient Volga terraces, developed along the left bank of the Volga River. At the present time, the geology of the Volga region is characterized by 4-5 terraces of different ages, which were formed during the quaternary period under conditions involving interrupted tectonic territorial elevations (Geology of the USSR, Volume XI).

The highest low-quaternary terrace, which is located at an absolute height level of 120-65 meters, resembles the Pliocenic syrts and cannot be distinguished from them in terms of relief. But its outer edge is reflected by a clear and smoothed out deluvial projection. Beneath this projection stretches a correctly discernible, broad (up to 35 km) and slightly separated middle quaternary terrace having a negligible slope and surface height markings of 65-45 meters; the terrace is genetically linked to the Dnepr glaciation period.

Less developed and interrupted flooded terraces of the upper-quaternary erosion-accumulation generations are found at the lower hypsometric levels. The complex of flooded terraces of the Volga left bank region extends for a considerable distance from the Volga upwards along the valleys of its principal tributaries.

Based upon the review carried out, the conclusion can be drawn that the orographic and geological conditions on the territory of the Middle Volga and Pre-Ural regions are very changeable elements of nature from a spatial standpoint; thus they exerted a comprehensive and intensive effect on the formation of the soil cover, particularly on the genesis, geography and regional peculiarities of the chernozem soils.

Climatic Conditions

The climate in the Middle Volga and Pre-Ural regions, being of the same type, is characterized by appreciable and large regional and local peculiarities.

Owing to the great size of the territory -- more than 5° in latitude and 10° in longitude -- an extensive thermal reaction is manifested that is conditioned by the varying amounts of solar radiation experienced throughout the year: from 85-90 kilocalories in the north to 110-115 kilocalories in the south, the annual radiation balance changes respectively from 28 to 35 kilocalories per square centimeter of surface. Regular zonal changes in the hot air regime are associated with the radiation conditions in the principal features -- an increase in the positive average annual and average monthly temperatures for the warm period and its duration from north to south.

In addition to radiation conditions, the hot air regime is also affected to a considerable degree by the peculiarities of atmospheric circulation, determined by the geographical location of the territory within the continent, to the east of the Russian plain: the unstable and variable arrival of moderately warm and damp ocean air masses from the Atlantic, cold arctic air, dry continental or cooled air masses from Siberia or warm dry air from the steppe and desert areas of central Kazakhstan and Central Asia. This involves great fluctuations in the air temperatures both on a perennial basis and for individual years and seasons, with the possibility of great anomalies in current weather conditions. All of this determines to a considerable degree the continental climate of the Middle Volga and Pre-Ural regions (see Table 1).

A typical feature of the temperature regime is the sharp contrast between the summers and winters, expressed by a broad range of average temperatures during the coldest (January) and warmest (July) months -- from 31.5 to 37.5° Centigrade -- or an absolute annual amplitude in air temperature of 80-88° Centigrade (from -33-50° Centigrade to 36-42° Centigrade).

Winter lasts for 140-170 days and summer (with temperatures higher than 10° Centigrade) -- 132-155 days. The total amount of positive temperatures (higher than 0° Centigrade) annually fluctuates from 2,300 to 3,000° and active temperatures (higher than 10° Centigrade) -- from 2,000 to 2,750°.

The annual course of the temperature is characterized by a rapid increase in warmth during the spring, with frequent reoccurrences of cold weather. The spring period is on the whole brief, approximately 25-30 days. Autumn lasts considerably longer (by 1.5 to 2 times) and the conversion over to a stable temperature regime takes place rather gradually.

Depending upon the relative influence of air masses of a particular origin, the thermal zoning for the territory under review shifts noticeably and the overall direction created for a change in the air temperature is from the north northwest to the south southeast. The degree of continential type conditions increases in the same direction: in the western part of the territory, occupied by the Pre-Volga Elevation and more susceptible to penetration by air from the Atlantic, the climate is less continental than that for areas lying at the same geographical latitude but to the east of the Volga River.

Table 1. Climatic Indices in the Zone of Distribution of Chernozem Soils (Middle Volga and Pre-Ural Regions)

Географические пункты (1)	(2) Среднегодовая температура воздуха	(3) Сумма положительных (выше 0°С) температур	(4) Сумма активных (выше 10°С) температур	(5) Средняя температура воздуха в самом теплом месяце	(6) Средняя температура воздуха в самом холодном месяце	(7) Показатель континентальности климата	(8) Годовая амплитуда температуры воздуха (абс.)	(9) Сумма осадков за год	(10) Сумма осадков за период с температурой > 10°	(11) Гидротермический коэффициент за теплый период с температурой > 10°С
	(12) град. С							(13) мм		
(14) Северная окраина зоны										
(15) Сергач (Горьковская область)	3,4	2587	2212	19,4	−12,4	31,8	80	480	268	1,2
(16) Чебоксары (Чувашская АССР)	2,7	2458	2085	18,8	−13,0	31,3	82	472	261	>1,2
(17) Мензелинск (Татарская АССР)	2,3	2482	2106	18,6	−14,2	32,8	85	435	239	>1,1
(18) Бирск (Башкирская АССР)		2316	2183	19,2	−14,3	31,5	85	483	249	>1,1
(19) Караидель (Башкирская АССР)		2297	1024	18,0	−15,7	33,7	87			
(20) Средняя часть зоны										
(21) Саранск (Мордовская АССР)	3,9	2720	2365	19,8	−11,7	31,5	81	459	260	1,1
(22) Ульяновск	3,2	2640	2285	19,0	−13,8	33,4	88	434	248	1,0
(23) Куйбышев (обсерватория)	3,8	2860	2540	20,7	−13,8	34,5	82	372	199	0,8
(24) Бугуруслан (Оренбургская область)	3,0	2707	2304	20,2	−14,3	34,5	85	419	201	0,8
(25) Бугульма (Татарская АССР)	2,1	2369	2020	18,7	−14,7	33,4	81	428	226	1,1
(26) Стерлитамак (Башкирская АССР)		2202	2328	19,9	−15,5	35,4	–	452	225	0,9
(27) Оренбург	3,2	3018	2719	21,5	−15,8	36,8	84	369	195	0,7
(28) Южная часть зоны										
(29) Саратов (опытное поле)	4,8	3019	2723	21,5	−12,0	33,5	78	370	190	0,7
(30) Пугачев (Саратовская область)	4,7		2710	22,6	−13,0	35,6	84	318	177	0,7
(31) Большая Глушица (Куйбышевская область)	4,0	2980	2610	21,8	−14,0	35,8	87	322	180	<0,6
(32) Илек (Оренбургская область)	4,0	3066	2756	22,6	−14,8	37,4	83	354	174	<0,6

Key:

1. Geographic points
2. Average annual air temperature
3. Total amount of positive (higher than 0°) temperatures
4. Total amount of active (higher than 10°) temperatures
5. Average air temperature during warmest month
6. Average air temperature during coldest month
7. Index of continental climate
8. Annual amplitude in air temperatures (absolute
9. Total amount of annual precipitation
10. Total amount of precipitation during period with temperature > 10° Centigrade
11. Hydrothermal coefficient for warm period with temperature > 10° Centigrade
12. Degrees Centigrade
13. Millimeters
14. Northern outskirts of zone
15. Sergach (Gor'kovskaya Oblast)
16. Cheboksary (Chuvash ASSR)
17. Menzelinsk (Tatar ASSR)
18. Birsk (Bashkir ASSR)
19. Karaidel' (Bashkir ASSR)
20. Middle portion of zone
21. Saransk (Mordovian ASSR)
22. Ul'yanovsk
23. Kuybyshev (observatory)
24. Buguruslan (Orenburgskaya Oblast)
25. Bugul'ma (Tatar ASSR)
26. Sterlitamak (Bashkir ASSR)
27. Orenburg
28. Southern portion of zone
29. Saratov (experimental field)
30. Pugachev (Saratovskaya Oblast)
31. Bol'shaya Glushitsa (Kuybyshevskaya Oblast
32. Ilek (Orenburgskaya Oblast)

The heat regime in individual parts of the territory changes more or less considerably depending upon the orographic situation. For example, in the Pre-Ural zone a noticeable influence is exerted by the cooling effect of the Ural mountain system; this same influence on climate is manifested in a weak form in rayons of the Bugul'minsko-Belebeyevskaya Elevation, the Zilairskoye Plateau and the northern edge of the Obshchiy Syrt.

It can be stated that the relief (its forms, size, exposure) is the most constant and indluential factor of the local changes in the thermal regime (and also moisture and other elements of the climate) on the remaining territory of the Volga and Pre-Ural regions.

Systematic observations of a network of meteorological stations have shown that elevations (syrts, watershed plateaus), compared to adjoining and relatively low plains and valleys, are characterized by lower (by 75-100° Centigrade) annual total amounts of active air temperatures for each 100 meters of elevation; moreover, elevations are distinguished by a longer frost-free period (by 15-20 days) and less amplitudes in temperature fluctuations, for both daily and annual cycles, and with the exception of low areas in the vicinity of large water areas of the Volga, Kama and other large rivers, where the effect of the water areas as accumulators of summer heat is felt in the coastal zones during the autumn period.

The differences in the moisture conditions of territories, which are caused by atmospheric precipitation and which are dependent upon the peculiarities of air circulation, generally coincide with the spatial changes in the thermal conditions. The northwestern and western rayons of the Volga region and the northern rayons of the Zavolzh'ye and Pre-Ural regions receive relatively raised and more constant (in a perennial cycle) amounts of precipitation on the order of 450-480 mm annually (in places up to 500 mm); in the middle zone of the territory, amounts on the order of 370-450 mm prevail and in the southern zone -- 320-360 mm. Moreover, in addition to a decrease in the average annual amount of precipitation, the irregular occurrence of such precipitation is increasing from year to year and season to season and a sharp increase is also taking place in the repetition and duration of extremely dry periods.

Based upon the moisture conditions and taking into account the degree of warmth and precipitation during the period of most active plant growth, the following regions are isolated: region of adequate moisture, in which the GTK [gidrotermicheskiy koeffitsiyent; hydrothermal coefficient] is equal to or somewhat higher than 1 (input and expenditure of moisture are balanced); region of lowered or weak moisture conditions (with a GTK of 1-0.8); region of insufficient moisture conditions (GTK 0.8). The geographical location of these regions and the configuration of their borders is more complicated than the overall plan for latitudinal zoning.

An important role in the formation of the geographic picture of atmospheric moisture is played by such large orographic elements as the principal watersheds of the Pre-Volga Elevation, which embrace the flows of the principal moisture-carrying Atlantic currents, by the Bugul'minsko-Belebayevskaya Elevation with its adjoining elements of the High Zavolzh'ye region and by the Ufa Plateau and the Pre-Bel'skaya Zone of the Pre-Ural region, which accumulate additional moisture owing to raised hypsometric levels.

Local peculiarities of relief, the hydrographic netowrk and the vegetative cover and the condition of the soil's surface affect to a considerable degree the moisture conditions in small portions of the territory and even in small regions having uniform quantities of atmospheric precipitation. This effect is manifested through the redistribution of moisture from falling rain and snow, depending upon the surface slopes, the wind conditions and the exposure of individual elements of the relief. The varying amounts of surface run-off and the intensity of moisture evaporation are associated with these same conditions and, as a result, a small spatial heterogeneity for the water regime of the soil is created. In particular, the local relief conditions and the condition of the surface exert a considerable influence on the distribution of the snow cover, which is closely associated with the depth and duration of the period of winter freezing of soil, a factor which is of considerable importance from the standpoint of ecology and soil-formation.

The brief review furnished above on the principal climatic conditions -- heat and dampness -- reveals that the territory of the Volga and Pre-Ural regions of the chernozem zone is characterized by a climate regime that is dryer, more continental in nature and spatially more variable than the climate of the adjoining central Russian province. Only the western edge of the Volga region -- the central rayons of the Mordovian ASSR and the extreme western rayons of Saratovskaya Oblast -- have conditions similar to the latter.

The considerable range of variability in climatic conditions within the borders of the Volga and Pre-Ural regions is considered to be one of the principal factors underlying the spatial changes in natural landscapes, the geography of the soil cover and the genetic diversity of the soils. However, it would be incorrect to assume that the formation of the latter is controlled entirely by climatic parameters: the facts indicate that soils of different genetic types, for example leached chernozems and grey forest soils, can be found under identical climatic conditions.

Landscape Zones and Vegetative Cover

The chernozem soils in the Volga and Pre-Ural regions lie in two landscape zones -- forest steppe and steppe -- the geographic positions of which generally involve changes in the climatic conditions, mainly in connection with the degree of dampness in the climate. The forest-steppe zone is bow-shaped and embraces a large northern portion of the territory; it drops towards the south both in the west, in the Pre-Volga region, and in the east, in the Pre-Ural region; it conforms to regions having adequate or a weak deficit of moisture (GTK 1.2-1; 1-0.8). The steppe zone includes the southern, extreme southwestern and southeastern regions of insufficient and unstable moisture (GTK 0.8-0.7 and less).

The actual picture of the placement of the forest-steppe and steppe areas is more complicated than the general plan, since the vegetative cover -- the principal spokesman for natural landscape -- is dependent in its formation upon many factors of both a modern ecological and also a historical-genetic and peleogeographic nature. As a result and with no connection to the climatic conditions, a trend is being observed in some areas wherein forests are being transformed from an adjoining forest zone not only into a forest-steppe but also a steppe zone and, conversely, vast purely steppe regions are being converted into forest-steppe zones.

As is well known, the borders between natural landscape zones are not sufficiently clear if they are not determined by large natural boundaries. The Volga River, from Kuybyshev to Vol'sk, serves as just such a boundary separating the forest steppe right bank region from the Volga Steppe region. The valley of the Bol. Kinel' River also serves as such a boundary separating the forest-steppe and steppe zones in the Volga region (L.I. Prasolov, S.S. Neustruyev, A.I. Bessonov, 1903-1916).

The middle Volga and Pre-Ural regions are territories of high farming development, with many areas having been developed many years ago. Economic activity has altered the natural environment substantially and, in particular, it has disrupted the vegetative cover in terms of both the composition of the vegetative types of associations and the contours of their spread.

The Pre-Volga forest-steppe region (to the west of the Volga River), especially its northern portion, is distinguished by a high level of forestation and this is manifested in the modern natural aspect of this territory. Here there are regions in which, beyond any doubt, forests having large forest tracts predominate. Moreover, a portion of these tracts can be viewed either as regional projections or as isolated islets of a neighboring forest zone. Their assignment to the high levels of the Pre-Volga Elevation relief underscores their origin from the ancient non-glacial sanctuaries of forest vegetation during the glacial period of the Russian plain.

The basic types of forest vegetation in the Pre-Volga forest steppe region include the broad-leaf forests consisting of oak, maple and linden trees, with ash and elm trees (complex oak groves) in some areas and mixed pine-broad-leaf forests including birch trees. Pure pine forests (mainly on sandy terraces) have spread to a considerable degree.

The oak groves of the northern forest-steppe regions (Gor'kovskaya Oblast, Chuvash ASSR) are distinguished by a closeness of the timber stands. Here one encounters pine trees and the grass cover contains such taiga-forest plants as majanthemum, pyrola, oxalis and wood reed (Stankov, 1951; Averkiyev, 1935, 1947). The oak groves in the central forest-steppe rayons of the Pre-Volga region are thinned out; here there is well developed undergrowth which includes hazel nuts with spindle tree and a strong grass cover consisting mainly of goutwood and hairy sedge, with the noticeable participation of mixed grasses -- onion grass, meadow grass and others. In the more dry areas of relief or in the southern third of the forest-steppe region, the oak groves are severely thinned out, the trees are not very tall and quite often a closed timber stand does not form. Rather there are groups among which meadow-steppe mixed herbs rich in types form to a strong degree. These groups are bordered by shrubs -- honeysuckle, dog rose and spirea. Quite often the meadow-steppe and steppe grasses in such oak groves penetrate under a cover of more dense timber stands.

With a considerably greater spread of the forests during the pre-culture period compared to the present time, more or less treeless steppe areas have remained between them since time immemorial. There can be no doubt but that such areas were utilized by the population primarily as arable land. Geobotanical data has enabled us to define the virgin land vegetation of exposed forest-steppe areas as being mainly either meadow-steppe or rich-grass-mixed herbs in nature. However, it is quite probable that an important role was played in the past by feather grass, mixed herbs-sod-grass (with feather grasses and sheep's fescue) "true" steppes. The latter supposedly predominated in the southern part of the Pre-Volga forest-steppe and to the south of the Syzran' River.

The forest-steppe lying to the east of the Volga River and before the foothills of the southern Urals, undergoes substantial changes throughout its extent, changes which are noticeably associated both with general geographic changes in the climate (mainly with an increase in continental conditions towards the east) and also with the regional peculiarities of the relief, ground and soils and local climatic conditions. First of all, one notices that the overall degree of forestation in the territory is comparatively lower than that for the Pre-Volga forest steppe region; treeless steppe elements of the landscape predominate to a considerable degree over the forest elements. More often than not the forests are scattered in the form of small groves on the summits and along the slopes of ravines and river valleys and quite often they form large isolated tracts.

In the Zavolsh'ye forest-steppe and prior to the Bugul'minsko-Belebeyevskaya Elevation, the forests are represented by several impoverished oak groves -- with lindens, maples and elms, but without ash which has not made the transition over to the left bank of the Volga River. Beyond the city of Belebey, oak is often replaced by linden, maple or elms and in some areas by birch. In the Belebey region there is an area of light birch forest-steppe which appears almost Siberian in nature and in which oak groves are completely absent. This is obviously the result of the colder and more severe local climate and the peculiarities associated with the history of development of the vegetation found in the Southern Urals and Pre-Ural region (Krasheninnikov, 1937, 1941; Mil'kov, 1950).

The steppes created a background of natural landscape in the Zavolzh'ye forest-steppe region, forming vast treeless regions in some areas (Chistopol'skiy

Rayon along the left bank of the Kama River, from the Volga to the Sheshma rivers; Cheremshano-Kondurchinskiy Rayon, which occupies a strip of the left bank of the Volga to the south of Mayna River up to the lower reaches of the Bol. Cheremshana River and a large portion of the interfluvial area for the Cheremshana and Kondurchi rivers).

According to the geobotanical data, the restored vegetation of the treeless expanses of the Zavolzh'ye forest-steppe region during the pre-agricultural period was represented mainly by associations of the meadow steppe type, which in the northern part of the sone were transformed into steppe meadows and in the south -- into true steppes. The grass stands of meadow steppes consisted of sod grasses -- sheep's fescue, koeleria, meadow grass, certain types of feather grasses and hairy feather grass and partly rhizome grasses (oat grass steppe brome grass and others). The abundant and colorful mixture of herbs that appears in late spring and during the first half of the summer period also played a great role in the formation of the grass stand. Such meadow steppes in the forest-steppe zone of the Zavolzh'ye and Pre-Ural regions existed up until the middle of the 19th Century and they can still be found in some areas at the present time.

The meadow steppes of the forest-steppe zone of the Zavolzh'ye and Pre-Ural regions are characterized by associations having a predominance of steppe shrubs -- dwarf almond, steppe cherries, spirea, peashrub, broom and so forth, which show a preference for developing along the irregular and eroded sides of ravines, on the steep slopes of syrts or hills or in low areas of watershed plateaus; equally typical are the distinctive and thinned out broad-leaf mixed herb associations of the calcareous-rocky steppe, which are peculiar to steep and well exposed slopes, the summits of watershed areas, shikhans and other prominent elements of the relief having outcroppings of crude native rock on the surface.

The steppe zone, which includes the southern portion of the chernozem distribution in the Volga and Pre-Ural regions in its natural (undisturbed by man) condition, is characterized by almost a complete absence of forests in the watershed areas and the prevalence of frost and drought resistant perennial grass plant communities containing a predominance of sod grasses. In conformity with definite spatial changes in the ecological conditions, sub-zonal strips and smaller regions having a predominance of certain types and variants of steppe vegetation are differentiated in the steppe zone.

The landscape strip, which borders to the south and leads up to the forest-steppe zone, for the "true" or typical (according to Ye.M. Lavrenko) or exposed (according to I.I. Sprygin) steppes in their northern locations and for more damp relief positions, was represented by plant groupings resembling those for the meadow steppes of the forest-steppe zone, where a rich mixture of different herbs prevails. Such variants in the exposed steppes were particularly widespread in the northern portion of the transitional steppe strip in the Zavolzh'ye region (according to L.I. Prasolov), in the interfluvial areas for the Bol. Kinel' and Mal. Kinel' and the Mal. Kinel' and Borovka rivers and along the headwaters of the Bol. Kinel' and Toka rivers.

The principal area of the sub-zone of exposed steppes, which embraces the southern regions of the Pre-Volga area, a vast strip of the Zavolzh'ye region lying between the Samara River on the one hand and the Chagra, Chapayevskaya and Buzuluk rivers on the other and also the southern portion of the Orenburg Pre-Ural region, is characterized by a predominance of mixed-herb, sod-grass plant associations in which the principal role is played by sheep's fescue, narrow-leaf feather grass and oat grass and partly by koeleria, meadow grass and steppe timothy. Compared to meadow steppe regions, there are considerably fewer types and a lesser abundance of dicotyledonous mixed grasses. On broken relief, one finds associations of steppe shrubs and xerochalkophyllite associations of "rocky steppes", which are similar to the associations of forest-steppes.

As the climate becomes more dry, the mixed-grass, sheep's fescue, feather grass true steppes are transformed into feather grass steppes (according to V.V. Alekhin), thus forming a sub-zone of dry steppes. In the grass foundation for such steppes, Lessing feather grass together with broad-leaf cat-tail and sheep's fescue serve as an indicator; bulbous meadow grass participates to a considerable degree in the formation of late spring grass stands. The mixed grasses are small in number and they often include semi-shrubs -- sagebrush, pyrethrum, perennial plants having a short growing season and bulbous ephemerons which develop in the spring when the soil is saturated with thaw waters. During the middle of summer, a sharp period of semi-dormancy occurs in the development of the vegetation of the dry steppes. An important feature of the plant cover is the overall thinning out of the plant stand and the predominance of incomplete and semi-closed associations: among the spore mats of grasses and the bushes of semi-shrubs and mixed grasses, open plots of soil remain in which, following rainfall, low plants develop.

The steppe zone of the Volga and Pre-Ural regions is an area of high farming development. However the extensive development of this area began rather recently -- 2-3 centuries ago. Moreover, during the first half of this period the farming was extremely extensive, nomadic and scattered. Thus the steppe plant cover destroyed by plowing and the grazing of livestock could periodically be restored naturally by raising it more or less to the initial virgin land condition.

Some Questions Concerned with Paleogeography, Paleopedology and the Evolution of Soils.

The Volga and Pre-Ural regions, being mainly an extra-glaciation territory, appear as an ancient denudation-accumulative plain within which surfaces of different ages and related to definite heights stand out. The oldest surface dates back to the end of the Mesozoic era. Throughout the quaternary period, the territory under review developed mainly in the absence of a hydromorphic regime, with the exception of the ancient valleys of large rivers.

The evolution of a majority of the soils in the territory studied can be presented in association with the evolution of the vegetation and the migration of the vegetative zones as a result of fluctuations in climate during the period of development of the soil cover. Despite the fact that the Volga and Pre-Ural regions constitute mainly an extra-glaciation area, glaciations of the Russian plain throughout the course of the quaternary period undoubtedly exerted a substantial influence on the activity of the denudation-accumulative processes and on the development of the hydrographic network. It can be stated that the arrangement of the surface and the overall formation of the landscape, which closely resembles the modern landscape, took place at the beginning of the Holocene epoch. It was obviously at this same time that the formation of the soil cover began, the features of which can still be traced in the structure and properties of modern soils.

The spore-pollen analytic data obtained and summarized by M.I. Neyshtadt, V.P. Grichuk and N.I. P'yavchenko sheds some light on the general features of the paleogeography and evolution of vegetation in the Volga and Pre-Ural regions during the period of time commencing with the early Holocene epoch. According to their materials, the climatic changes during this period in the southern and southeastern European part of the USSR (to the south of Kaluzhskaya and Gor'kovskaya oblasts) had a relatively low amplitude of fluctuations and did not bring about substantial changes in the physical-geographic conditions or in the landscape as a whole and the natural-landscape zones were distinguished by definite stability. This applied in particular to the zone of steppes, the borders of which were established on the given territory during the early Holocene epoch (Neyshtadt, 1957). In the opinion of V.P. Grichuk (1950) and N.I. P'yavchenko (1958), it can only be stated with regard to the steppes that a certain change took place in their vegetation structure, which was more xerophilous during the early Holocene epoch.

On the territory of the modern forest-steppe zone, during the early Holocene epoch, .I. Neyshtadt (1953, 1957) assumed the existence of thinned out pine-birch forests having a small mixture of broad-leaf varieties (oak, elm and linden trees), which spread extensively during the middle Holocene epoch (climatic optimum), moving southward into the area of northern steppes. During the late Holocene epoch, the borders for the spread of the broad-leaf varieties showed practically no change and yet the pollen spectrums reveal the presence of birch and at times pine trees. K.K. Markov and others (1950) tend to associate this circumstance with the economic activity of man, that is, with the cutting down of forests and the appearance of secondary forests.

Interesting materials on the paleogeography of the forest steppe in the Middle Volga region have been presented in the works by N.I. P'yavchenko (1950, 1958). Here, the author, based upon the data obtained from stratigraphic and pollen studies of peat bogs in Ul'yanovskaya and Kuybyshevskaya oblasts and in the Mordovian and Tatar ASSR's, draws the conclusion that during the past 6,000-7,000 years (absolute age of the peat bogs) no significant climatic fluctuations, movements of the vegetative zones associated with such fluctuations or sharp changes in the degree of afforestation took place in the mentioned territory. N.I. P'yavchenko's view of the dynamics of vegetation in the forest-steppe zone is similar to that held by M.I. Neyshtadt.

During the early Holocene epoch, with relatively dry and warm climatic conditions prevailing in the middle Volga region, a pine-birch forest-steppe existed which, 4,000-5,000 years ago (average Holocene), was replaced by a damp broad-leaf forest-steppe, with the broad-leaf varieties reaching this area from the southwest and the central chernozem oblasts. N.I. P'yavchenko assumed the presence of a maximum amount of forest land at the beginning of the late Holocene epoch; this land has been reduced sharply at the present time.

Thus, sharp changes did not take place in the climate and vegetative cover of the middle Volga and Pre-Ural regions during the post-glacial period. The vegetative cover, at least since the middle Holocene epoch (7,000 years ago), has appeared as a complicated association of forest-steppe and steppe, the border between which has not changed substantially since that time. The evolution of the vegetation ended with certain changes in the floral structure of the vegetative zones and obviously in a certain movement of the borders of the forest tracts within the forest-steppe.

These conclusions and also the geobotanical materials of I.I. Sprygin (1931) on pre-agricultural vegetation in the middle Volga region reveal rather convincingly that the overwhelming majority of the chernozem soils in the steppe and southern forest-steppe regions developed under grassy steppe and meadow-steppe vegetation. Moreover, the history of the formation and the arrangement of the surface of these territories testify to the fact that the hydromorphic stages did not play a substantial role in their formation.

Leached chernozem soils, as a sub-zonal sub-type, were formed in the relatively damp forest-steppe under the influence of meadow-steppe vegetation without being affected by the forests. The paleosoil studies carried out by P.V. Madanov and others (1967) provide a very good argument in support of this theory. Here a comparison was made of modern soils against soils buried under burial mounds in the Bronze Age (3,000-3,500 years ago). The authors convincingly revealed that the modern and buried leached chernozem soils are characterized by a very close similarity in the depth of their humus layers and also by practically identical properties -- humus content, its qualitative composition and so forth.

Podzolized chernozem soils, the areas of which are located in the peripheral portions of existing (or existed in the past) forest tracts, in the direct vicinity of them or in areas of settled forests are genetically associated both with forest and meadow-steppe vegetation. Two basic methods can be presented for their formation: they could have been formed along the forest edges and borders of steppe tracts or under a canopy of forests of the park type, where wood vegetation is combined with an abundant amount of grass cover. The other method consists of their having experienced an alternating effect from meadow-steppe and forest vegetation owing to a certain amount of movement of their borders.

A comparison of chernozem soils which develop on loose deposits of surfaces of different ages reveals that the differences in their structure and properties are minimal, since the denudation-accumulative processes which took place during the glacier epoch smoothed out the former differences associated with the age and evolution of the relief.

The complete analogy between the modern chernozems and chernozem soils buried 3,500 years ago, developed on deposits of the same age, reliably testifies to the fact that during the second half of the middle Holocene epoch the chernozems in the Middle Volga region acquired a completely formed profile and have been in a "climax" situation for an extremely long period of time.

Brief Review of the Soil Cover

The area of the Volga-Pre-Ural sector of the chernozem zone should not be viewed as a region in which chernozem type soils predominate in all areas; owing to a considerable degree of heterogeneity in natural factors, the soil cover in a number of portions of the territory under review contains soils of other genetic types in addition to chernozem soils. This applies for the most part to the northwestern, western and northeastern parts of the forest-steppe belt (Pre-Volga, PreUral forest-steppes), where during the pre-cultivation period vast areas were occupied by broad-leaf forests, which adjoined the forest zone in the north. Thus grey forest soils predominate in the soil cover found in regions of Gor'kovskaya Oblast and the Chuvash ASSR on the Pre-Volga Elevation. The chernozem soils form only isolated islands and their areas are generally smaller. The same holds true for chernozems found in the soil cover of the Ufa Forest-Steppe Plateau (to the northeast of the Bashkir ASSR) and the Kungursko-Krasnoufimskaya Forest Steppe in the Pre-Ural region (to the south of Permskaya Oblast).

To the south of the northern border of their distribution in the middle portion of the forest-steppe belt, the chernozem soils predominate in the soil cover and in a number of regions they cover vast territories almost entirely. Still in other territories they alternate with more or less large tracts of grey forest soils (and partially with other soil types), thus reflecting the dual nature of the landscape in the forest-steppe belt. Thus the ratio for areas between the chernozem soils and the grey forest soils of the right bank of the forest-steppe portion of Ul'yanovskaya Oblast is roughly 2:1 and in the southern forest-steppe of the High Zavolzh'ye region (Ul'yanovskaya and Kuybyshevskaya oblasts) -- 4-5:1 and more.

The steppe belt of the Volga and Pre-Ural regions is characterized on the whole by a complete predominance of chernozem soils in the soil cover, accounting for 90-95 percent of the area. The remaining portion is occupied by flooded lands, meadow-chernozem soils, forest soils in some areas, solonetz complexes and others. But towards its southern edge the distribution of the chernozem soils once again becomes less intact; initially they are interrupted by the appearance of dark chestnut soils on the steep lower portions of syrt slopes and thereafter they diminish to detached contours associated with the summits of watersheds and, finally, they yield their importance to soils of the chestnut type.

Thus, based upon the above, it would appear that chernozem soils in the Volga and Pre-Ural regions are found in two natural-geographic zones -- forest-steppe and steppe, and this creates the first view concerning the disparity between the bioclimatic and soil zonality. However, it disappears when studying the geography of the soil sub-zones isolated on the basis of a predominance of particular chernozem soil sub-types.

The soil-cartographic materials accumulated over the course of several decades by many researchers and soil scientists have established a picture of unquestionable territorial concentration of podzolized, leached and typical (mainly fertile) chernozem soils in the forest-steppe zone: typical and common chernozem soils in the sub-zone of the true steppes; southern chernozem soils in the southern and more dry steppe sub-zone. Sub-zonal articulation of the chernozem zone is manifested very clearly and geographically sequentially (from north to south) in the middle portion of the Volga region, roughly between 50 and 54° east longitude. To the west of the Volga River on the Pre-Volga Elevation, the forest-steppe zone, as mentioned earlier, is quite well advanced towards the south and does not have a clear natural border; to the east of the 54th meridian the latitudinal placement of the chernozem sub-zones is distorted noticeably by the meridional orientation of the principal orographic and hydrographic elements of the territory.

In accordance with "Soil-Geographic Regionalization of the USSR" (1962), the Volga and western Pre-Ural regions of the forest-steppe and steppe natural zones belong to two provinces -- the middle Russian (partially) and the Zavolzh'ye (fully) for each zone. Within these provinces, soil districts and "groups of districts" have been noted and partially isolated. These districts are subsequently broken up into soil rayons having relatively the same relief, soil cover structure, plant cover and microclimate peculiarities.

Commencing with the first remarkable experiment in complex landscape-soil regionalization in the former Samarskaya Province, published by Neustruyev, L.I. Prasolov and A.I. Bessonov in 1910, various programs have been developed by many individuals and collectives for overall natural-geographic and soil-geomorphological, soil-reclamative and agro-soil regionalizations, carried out mainly in individual oblasts and republics.

These works more or less supported a zonal-sub-zonal landscape-geographic basis and its accompanying geomorphological-genetic and quantitative (with regard to areas) principle of isolation of soil regions. However, the degree of divisibility and the taxonomic level of the latter cannot be the same: in some instances, a vast territory was isolated having an extremely heterogeneous relief, parent rock and soil cover; in other regions, they were reduced to very small territorial segments, roughly corresponding to individual geo-morphological elements. For a monographic summarization, systematization and description of the chernozem soils in the Volga and Pre-Ural regions, it is considered more advisable to employ as the basis a network of consolidated natural-geographic regions which, in terms of their content, conform to the district groups of the mentioned all-union regionalization in 1962 (see Figure 1).

Five natural-geographic regions are singled out on the territory of the Volga and Pre-Ural area studied: 1 - Pre-Volga forest-steppe; 2 - forest-steppe of the Zavolzh'ye and Pre-Ural regions; 3 - Pre-Volga steppe; 4 - Zavolzh'ye and Pre-Ural steppe and 4a - Low (terrace) Zavolzh'ye steppe.

Conclusion

The chernozem soils in the Volga and Pre-Ural regions are the farthest eastern representatives of soils of this type on the territory of the European part of the USSR. Distinctive natural conditions, a continental climate in all of its aspects, a considerable lithological heterogeneity in the soil-forming rock with an extensive distribution of calcareous clay deposits and, finally, a predominance of surfaces having raised and very broken relief -- all of these factors served to bring about the substantial differences in the soils and soil cover between the given region and regions further to the west.

On the whole the chernozem soils in the Volga and Pre-Ural regions are characterized by a contrasting water-thermal regime. They are characterized by more intense winter freezing conditions (roughly three times greater than that for soils in the central province), a very brief snow-thawing period and a severe and prolonged period of heat during the summer period. The mentioned peculiarities are intensified by the wind transfer of snow, by a reduced amount of precipitation and, in this regard, by and increase in solar radiation and a reduction in the consumption of heat for moisture evaporation purposes. Moreover, the features of a continental climate are expressed to a greater degree in southern chernozem soils.

The water regime of Volga and Pre-Ural region chernozem soils, particularly steppe chernozems, is extremely tense. Distinct from the soils found in the western provinces, the chernozem soils in the region under review are characterized by a good moisture supply in the autumn and spring (following the thawing of the soils, with winter precipitation playing a considerably smaller role, and also by a reduction in the quantitative indices for moisture and a substantial decrease in the amount of active moisture circulation. During dry years, the probability of which is quite high in the Volga region, there may be an extended absence of accessible (for the plants) moisture in the upper one half meter layer of chernozem soil, particularly common and southern chernozems. Such moisture may not even appear until the second half of the summer period, a trait that is not typical of regions having a modified continental climate.

The peculiarities of the water-thermal regime are determined to a considerable degree by the biological status of the soils and by the direction and intensity of the biochemical processes. The contrasts in the thermal regime of the chernozem soils, the reduced water supply and lowered thickness of the layer of active moisture circulation and the extended pauses in the activity of the microorganisms represent one of the principal causes of the formation of chernozem soils having more shallow humus layers and profiles on the whole than other regions in the European part of the USSR and with a considerably higher accumulation of humus in the upper portion of the profile. Winter cooling and summer overheating, combined with the lithologic-meneralogical peculiarities of the soil-forming rock (clay mechanical composition and high content of clay minerals of the montmorillonite group) cause cracking, particularly in steppe chernozem soils, and they promote structural differentiation of the profile. The active migration of solutions, so characteristic of typical and common chernozem soils, is considerably weaker here. In the majority of instances, leached and podzolized chernozem soils have a clearly glazed profile. The nature of the soil-forming rock and the large humus content in the region's chernozem soils result in a high absorption capacity (on the order of 45-55 milliequivalents), almost complete saturation of the absorbent complex by the bases, among which calcium predominates and a close to neutral reaction of the medium.

From the standpoint of agricultural production, the chernozem soils in the Volga and Pre-Ural regions represent on the whole a valuable arable land fund. The favorable water-physical properties, the large supplies of humus, nitrogen, phosphorus and potassium and also their compound forms provide a high potential fertility for these soils. For example, easily hydrolized nitrogen constitutes a considerable portion of the gross supplies of nitrogen; it is an important reserve for plant nutrition. Phosphorus-organic compounds, which serve as an important source for plant-accessible phosphorus, predominate among the phosphates. The hydrolysis of these compounds is carried out mainly using the biochemical method and it is dependent upon the activity of the appropriate ferments.

Thus the task of supplying the plants with nutrients must be carried out not only by applying mineral (primarily phosphorus) and organic fertilizers but also by activating the biochemical processes. In particular, this is promoted by applications of certain forms of nitrogen fertilizers and micro-elements.

Assuming a high potential fertility in the Volga and Pre-Ural region chernozem soils, the chief factor limiting the development of high yields is that of unstable moisture conditions for the agricultural crops. A review of the water regime for chernozem soils in the region has revealed that measures aimed at accumulating and retaining moisture must be carried out in two directions. First of all and compared to other regions, greater importance is attached to carrying out snow retention measures in the Volga and Pre-Ural region. The retention of snow out on the fields is extremely important in the case of broken relief and strong winds, it promotes slower thawing of the snow, it thus reduces the unproductive flow of thaw waters over frozen surfaces and it ensures a supply of moisture for the soil during the early spring period.

Another complex of measures for improving the supply of moisture for the plants must be directed towards reducing the unproductive consumption of moisture for physical evaporation, which is considerable in the spring prior to the closing of a grass stand and in the autumn during the post-harvesting period. It was pointed out above that the total amount of this consumption ranges from 1/3 to 1/2 half of the total amount of annual precipitation. Great importance is attached in this regard to developing special agrotechnical methods and a special and qualitatively different crop rotation plan structure.

The lithological heterogeneity of the soil-forming rock and the proximity to the surface of native deposits, particularly in regions having a raised and broken relief, have produced a considerable variety in the chernozem forms and, as a result, a number of special kinds and types of chernozem soils have been singled out. Among the kinds encountered, special attention should be given to the weakly-differentiated, compact, residual-calcareous an saline chernozem soils. These differ from their usual analogs in terms of a number of properties and thus a special approach is required for their utilization in agriculture. For example, weakly-differentiated chernozems having a light mechanical composition are characterized by relatively low supplies of nutrients, a lack of structure and a low water capacity and thus they require increased dosages of organic and mineral fertilizers, the use of green manure crops and the cultivation on these soils of such crops as potatoes, peas, buckwheat and millet.

The compact chernozem soils require first of all improvements in their physical properties, since they differ in terms of low water permeability, low porosity of aeration, high water retention capability and accordingly a low range of active moisture; as a result of all this, the agricultural plants are subjected to soaking during damp years and during normal and dry years they suffer from a shortage of moisture.

Residual-calcareous chernozem soils having a fully developed profile in terms of a majority of their properties and their use in production operations, closely resemble their usual analogs. However, among the soils of this type, residual-calcareous chernozem soils having a shallow profile warrant special attention; owing to the proximity to the surface of compact native rock stratifications, they should ideally not be included in the arable land fund but rather used for haying and pasture purposes.

Still another approach is required for saline chernozem soils, the reclamation of which varies and is dependent upon the causes and degree of alkalinity.

The need for employing a special approach for utilizing eroded chernozem soils also merits special attention. The objective causes of the widespread appearance of such eroded land include: the presence of vast areas having raised and broken relief and a shallow cover of loose deposits; the considerable participation in the soil cover of especially erosion-prone components -- weakly-differentiated and calcareous chernozem soils; specific nature of water-thermal regime. Some influence has been felt in this regard by the ancient and extensive agricultural development of the territory and by disruption of the natural ecological balance (reduction in the area of watershed forests, unlimited plowing of slopes and so forth).

The natural conditions of the region are such that the enumerated generic and erosion forms of chernozem soils rarely form areas that are considerable in size. Typical features of the soil cover structure include a complicated nature, small dimensions and a high contrast among components which, as a result of differences in the chemical and physical properties, often possess different productive qualities.

Thus, based upon the above, it would appear that a scientifically sound and differentiated approach is required for utilizing the land resources of the Volga and Pre-Ural regions, while taking into account the local peculiarities of the soils, rock, relief and other natural factors associated with agricultural production.

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CLASSIFICATION, APPLICATION OF COMPLEX FERTILIZERS DISCUSSED

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/Article by A. V. Peterburgskiy, Moscow Agricultural Academy imeni K. A. Timiryazev: "Complex Fertilizers and Their Importance and Application in the USSR*/

/Text/ An efficient classification of modern types of complex fertilizers is set forth. Their composition, properties and conditions of application in hydroponics, in hothouse facilites and under field conditions are presented. Their usually higher effect on the harvest and quality of crops, as compared with equivalent doses of N, P_2O_5 and K_2O in simple mineral fertilizers, is shown by numerous experiments.

Compound fertilizers contain two or three nutrient elements (P, PK, K or NPK). Depending on production techniques and agrochemical properties they can be subdivided into compound, combined and mixed.

Compound fertilizers represent one salt, whose anion and cation are absolutely necessary for plants (for example, $NH_4H_2PO_4$, KNO_3, $MgNH_4PO_4$ and potassium and ammonium polyphosphates).

Combined fertilizers consist of a number of salts including all the ions necessary for plants. Owing to the interaction and careful mixing of initial components and granulation in the process of production, these fertilizers are also characterized by a sufficiently uniform composition (nitrophoskas, nitroammophoska, urea phosphates, carboammophoskas and so forth). (Nitrophoskas are obtained by the decomposition of nitric acid apatite in a mixture with sulfuric or phosphoric acid with a subsequent addition of potassium chloride and granulation.)

*From the report to the 8th International Congress on Mineral Fertilizers with A. N. Kulyukin's participation.

Mixed fertilizers are the product of mechanical mixing of two or three simple fertilizers. Their capacity for caking during storage and transportation and for layer separation during application (especially, if the latter is carried out by spinner broadcasters) must be considered a significant shortcoming of such mixtures. Such a segregation leads to a more or less marked separation of fertilizer mixtures into initial components, which is extremely undesirable.

Our experiments (Peterburgskiy and Debretsoni, 1961a) disclosed that even under conditions of vegetative experiments corn assimilated less ^{32}P, N and K and developed the root system more weakly during an uneven distribution of fertilizers and this inevitably led to a considerable reduction in the harvest. Of course, this also occurs with mineral fertilizers.

The output of N, P_2O_5 and K_2O in the form of complex fertilizers reached 15% in the Soviet Union in 1975. By 1980 it will greatly increase (29%). In the future it is desirable to have at least 50% of the total amount of mineral fertilizers applied in farming.

Among compound fertilizers ammonium phosphates have become widespread in developed countries, especially in the United States. They have good physicomechanical properties and a high total concentration of N and P_2O_5 (up to 60-70%). In hundreds of comparative tests, as the sources of phosphorus and nitrogen (with leveled doses of NPK in all the studied variants) of ammophos and diammophos for all basic crops and on the most important types of soil in our country, it turned out that not in a single case were these compound fertilizers inferior to an equivalent mixture of simple fertilizers.

Conversely, in most experiments the effectiveness of ammonium phosphates was much higher. This can be seen from the summaries of experimental results (Kondrat'yev and Mamkina, 1968, 1973).

At the same time, it should be noted that, owing to a too wide nitrogen-phosphorus ratio, ammonium phosphates, without supplementing them with nitrogen and potassium, can be applied mainly as a local (sowing) fertilizer (to rows and holes). However, during basic application (with plowing under soil) ammonium phosphates must be combined with other nitrogen and potassium fertilizers and even mixed with the latter, and this, inevitably, increases farm expenditures on mixture preparation. Apparently, in such situations plant preparation of combined fertilizers on the basis of ammonium phosphates is more rational.

For example, a combined fertilizer containing 19% of N, P_2O_5 and K_2O and consisting of carbamide, ammonium phosphates and potassium chlorides is being studied in the United States (Araten, 1968). Carboammophoska was also obtained in the USSR (by mixing ammophos and carbamide and potassium chloride solutions; they contain 19.8% of N, P_2O_5 and K_2O). If KCl is not introduced, carboammophos can contain a total of up to 60% of N and P_2O (both in equal parts). The granules of the new fertilizers are three to five times stronger than those of urea and ammonium nitrate. Carboammophoska tests produced good results. We (Peterburgskiy and Shafran, 1971) also obtained such results for urea ammophos ($CO(NH_2)_2 \cdot NH_4H_2PO_4$) containing 30% of N and P_2O_5.

Magnesium ammonium phosphate ($MgNH_4PO_4 \cdot H_2O$) is only slightly soluble in water, but its constituent ions are well assimilated by plants. It contains 15-16% of magnesium, 10-11% of nitrogen and 39-40% of phosphorus--a total of 54-67%. Its production is much cheaper than that of an equivalent amount of the same nutrient elements in the form of simple fertilizers.

According to the results of our investigations (Peterburgskiy et al., 1972), it is advisable to use this fertilizer in hydroponics when growing vegetable crops on keramzit (table 1). Magnesium ammonium phosphate in a dose of 2-3 g of P_2O_5 per plant is introduced into small pots for growing seedlings. This dose of phosphorus (and of the magnesium accompanying it) is also sufficient for the formation of a rich harvest after the transplantation of vegetable crops into the ground. However, ammonium nitrate is sufficient only for the initial period of growth. Therefore, during the first period the nutrient solution supplied to the trays with plants should contain potassium and calcium cations, sulfate anion and trace elements and, subsequently, nitrate in the form of potassium nitrate is also introduced into it. When $MgNH_4PO_4 \cdot H_2O$ is introduced into small seedling pots, calcium is added to the solution before bloom and then the need of plants for Ca is met by the Ca of tap water with which salt solutions are prepared. Such a method greatly simplifies and lowers the cost of cultivation in hydroponics, because the preparation of a superphosphate extract and of a magnesium sulfate solution becomes unnecessary. Correction of the composition of the nutrient solution (during its repeated introduction) is also simplified. This has been confirmed by long-term tests of the recommended method. Table 2 present the results of one of the experiments, which shows that granulated and powdery magnesium ammonium phosphate provides the same effect. The same can be said with respect to its introduction into a small seedling pot, or an even distribution in the substrate. The same result as with the use of the water soluble salt of phosphoric acid was obtained in both cases. However, the quality of fruits had the tendency toward improvement in case of application of magnesium ammonium phosphate, although a little less phosphorus from it was assimilated. This means that it is better utilized by the plant from this source. Usually, the quality of fruits is also better than on a nutrient salt mixture.

We also obtained satisfactory results when growing cucumbers for seeds on magnesium ammonium phosphate and in an ordinary ground hothouse (table 2) on a leveled background of NK, especially with local application. It is well known that the quite rapid salinization of the substrate, in particular of soil, is the scourge of ground hothouses. This soil must be replaced periodically, which requires large expenditures. There is no doubt that, by applying concentrated compound fertilizers, it is possible to greatly prolong the use of soil in hothouses without renovation. It is to be hoped that with the development of industrial production of magnesium ammonium phosphate it will also find application under field conditions, especially on subacid soil poor in mobile magnesium.

Combined fertilizers. The following combined fertilizers are now produced in our country on an industrial scale: nitrophoskas and nitroammophoskas. The production techniques of the former were discussed above. Nitroammophoskas are obtained by the ammoniation of a mixture of nitric and phosphoric acid, addition (after concentration by evaporation) of potassium chloride and granulation. The content of N, P_2O_5 and K_2O at a ratio of 1:1:1 comprises 17.5% of each. Phosphorus is represented by ammonium phosphates, nitrogen, by ammonium nitrate and partially by NH_4CI and potassium, by its chloride and nitrate. The proportion of water soluble phosphates is very high (up to 90%), which is approximately 1.5 times higher than in nitrophoskas (55%). On the one hand, this lowers the cost of transportation, storage and application of nitroammophoska to soil and, on the other, requires much greater energy expenditures on the decomposition of phosphate raw materials and the production of extractive ortophosphoric acid. As numerous tests showed, in their effect on the harvest nitrophoskas and nitroammophoskas do not differ considerably. The superiority of both combined fertilizers over equivalent mixtures of simple mineral fertilizers was noted many times both in the USSR (Peterburgskiy, 1975; Stefanov, 1969; Gryzlov et al., 1971) and abroad (Baychi, 1964; Yenikov and Atanasov, 1971; Kovach, 1972; Latkovich, 1971).

In tables 3 to 5 we cite only three examples of a comparison of the effectiveness of combined fertilizers and mineral fertilizer mixtures in the cultivation of oat and barley potatoes on nonchernozem soil.

In another series of our experiments on soddy-podzolic soil it was established that the availability of nitrogen, phosphorus and potassium from nitrophoskas to plants is slightly higher than from superphosphate in a mixture with ammonium nitrate and potassium chloride. Probably, this is due to the more even distribution of combined fertilizer granules in soil. We would also like to note that in soil phosphates from nitrophoskas are less subjected to retrogradation than from superphosphate (Peterburgskiy and Vereykina, 1960; Belima, 1964). A better development of the root system of winter wheat and an increase in its adsorption surface with nitrophoska, which contributed to an increase in the yield of crop fertilizers, was also noted (Ustimenko et al., 1975; Khomenko and Moldovin, 1964).

In our vegetative experiments on soddy-podzolic soil conducted with Debretseni (1971b) we thoroughly investigated the importance of solubility of phosphates and of the granulometric composition in simple and combined fertilizers. The results showed the following: 1) the different granulometric composition of the studied fertilizers (powdery and granulated) had no great effect on the oat harvest and on the availability of phosphorus from fertilizers to plants if the content of water soluble P_2O_5 in them comprised about 50% of nitrate soluble P_2O_5; 2) the phosphorus of the fertilizer containing only water soluble P_2O_5 was assimilated better from granules, and the phosphorus of fertilizers containing only citrate soluble P_2O_5, when they were applied in a powdery state; 3) the availability of phosphorus, nitrogen and potassium from nitrophoskas is slightly higher than from the corresponding mixtures of simple fertilizers. This can be due to the more even distribution of nutrients in the particles of the complex fertilizer than during the application of a mixture of simple mineral fertilizers, which, moreover, can be separated into layers during sowing; 4) the calcium of superphosphate and other phosphoric fertilizers in the described experiments did not play any significant role in the calcium nutrition of oats.

On soddy-podzolic soil in Moscow Oblast we set up an experiment with an evaluation of the availability to oats of various compounds of phosphorus from nitrophoskas ("frozen" and carbonate) and a mixture of simple mineral fertilizers with the participation of superphosphate. The doses of N, P_2O_5 and K_2O were 40 kg per hectare in all variants, but phosphorus was calculated either according to the total content of P_2O_5 in the fertilizer, or according to the P_2O_5 occurring in an assimilated state. The experimental results are presented in table 6.

As can be seen from the figures presented in table 6, when calculating the dose of P_2O_5 in "frozen" nitrophoska and superphosphate according to its assimilated form, the grain harvest was absolutely the same and the removal of phosphorus was almost 6% lower than in nitrophoska. However, in case of carbonate nitrophoska, the grain harvest also proved to be 8% lower and the removal of phosphorus was 10% lower. But frozen nitrophoska contains only about 55% of water soluble P_2O_5 (of the assimilated) and superphosphate, no less than 75%. Carbonate nitrophoska does not have this form of phosphates at all. Therefore, as a source of phosphorus the first nitrophoska is not inferior to superphosphate and the second (as was to be expected) acts during the first year slightly more weakly than the popular phosphoric fertilizer.

Economic Effect From the Application of Mineral Fertilizers and Nitrophoskas

However, the economic effectiveness of combined fertilizers under production conditions, which can exceed the mixtures of simple fertilizers by 51% to 76% in this respect, is their main positive aspect (Peterburgskiy and Smirnov, 1968; Postnikov, 1964; Smirnov and Peterburgskiy, 1969; Torin, 1962; Peterburgskiy and Shafran, 1971; Peterburgskiy and Kolelishvili, 1973; Sorochinskiy, 1970; Arutyunyan, 1971; Isayeva, 1971 and 1972; Kalinichenko, 1968; Vinogradova, 1970 and many others).

The economic effect of nitrophoskas is the highest when they are applied locally (to rows, furrows and holes) during the sowing of grain crops and sugar beets and during the planting of potatoes. We shall cite only several examples.

Table 1. Harvest and Quality of Tomato Fruits of the Belyy Naliv Variety Depending on the Method of Application of Magnesium Ammonium Phosphate

Variant	Harvest kg/plant	Dry substance in fruits, %	Content per Raw Substance: Total sugars, %	Content per Raw Substance: Vitamin C, mg%	Content per Raw Substance: Carotin, mg%	Removal of P_2O_5 by harvest, mg/plant	Coefficient of phosphorus utilization, %	Phosphorus consumption on fruit formation, mgP_2O_5/kg
Control (Geissler's nutrient mixture)	2.420	5.36	2.01	25.9	1.52	1639	82	680
Magnesium ammonium phosphate in the form of granules into a small seedling pot	2.573	5.58	2.30	27.0	1.88	1422	71	550
$MgNH_4PO_4 \cdot H_2O$ in the form of powder into a small seedling pot	2.586	5.46	2.30	27.2	1.85	1494	74	575
$MgNH_4PO_4 \cdot H_2O$ in the form of granules evenly per vessel	2.366	5.45	2.32	25.6	1.85	1602	80	675
$MgNH_4PO_4 \cdot H_2O$ in the form of powder evenly per vessel	2.394	5.41	2.26	25.9	1.86	1618	81	680
$HCP_{0.05}$ 344 g								

Remark. The dose of P_2O_5 in all the experimental variants was 2 g per plant.

Table 2. Harvest of Cucumber Fruits and Seeds (TSKhA /Timiryazev Agricultural Academy/ Variety) Depending on the Methods of Application of Double Superphosphate and Magnesium Ammonium Phosphate in a Ground Hothouse (Peterburgskiy and Kulyukin, 1976)

Experimental variant 2 g of P_2O_5 per plant)	Fruit harvest, kg/square meter	Seed weight, g/square meter
K (background)	3.9	34.0
$K+P_{sup}$ locally	8.8	82.4
$K+P_{MAP}$ locally	9.4	90.5
$K+P_{sup}$ scattered	8.0	79.5
$K+P_{MAP}$ scattered	7.6	63.8
$HCP_{0.05}$	0.96	6.44

In our experiments conducted with D. M. Kolelishvili (1973) in Orlovskaya Oblast the net income per hectare of potatoes totaled 158.7 rubles from a mixture of simple mineral fertilizers and 237.6 rubles from nitrophoska. On the average, on a number of farms in Sverdlovskaya Oblast production tests on areas sown with spring wheat and potatoes showed that, if the net income from a mixture of simple mineral fertilizers is taken as 100, the following were obtained from nitrophoskas: with basic (presowing) application to a) wheat, 176 and b) potatoes, 151 and with row application (during sowing) to a) wheat, 155 and b) potatoes, 147 (Smirnov and Peterburgskiy, 1968).

Importance of Joint and Separate Application of N, P and K to Soil

It was noted above that an even distribution of a uniform mertilizer mixture in the soil layer, to which nutrients are applied, is of great importance for plants. To illustrate this point, we will discuss our vegetative experiments with corn (Peterburgskiy and Debretseni, 1961a). In the first experimental variant ammonium nitrate, superphosphate (tagged ^{32}P) and potassium chloride were carefully mixed with the entire mass of soil before vessels were packed with it. In the second variant each of these fertilizers was mixed with one-third of the soil batch and then by means of temporary partitions the vessel was divided into three sectors, placing one-third of the batch of soil fertilized with only one nutrient in each sector. Corn sprouts were transplanted into the center of the vessel (the partitions were removed first) with the distribution of the root system of corn into three parts (each strand in one sector).

In the first experimental variant each strand of roots found all the three nutrients in any sector from the very beginning. In the second variant, however, the appropriate strand at first could absorb only one nutrient (nitrogen, phosphorus or potassium), which was introduced into a given sector. Of course, with the development of roots they could also penetrate into other sectors, utilizing two or three food elements from fertilizers, not one.

Table 3. Comparative Effect of Nitrophoskas and Mixtures of Simple Mineral Fertilizers on Potatoes Under Conditions of Soddy-Podzolic Soil (Experiments by A. Peterburgskiy and A. Postnikov, 1969)

Experimental Variant	Basic application (com. of 18 experiments)		Application During Sowing: Manual (com. of 13 experiments)		Application During Sowing: With a potato planter (com. of 33 experiments)	
	Increase as Compared with Control, Quintals per Hectare					
	tubers	starch	tubers	starch	tubers	starch
Nitrophoskas	48.7	4.58	24.7	4.38	24.0	1.6
Ammonium nitrate, superphosphate and potassium chloride, quintals per hectare	46.1	3.74	22.9	3.56	5.7	0.5
	3.6	-	4.2	-	4.2	-

Remark. The harvest in control (without fertilizers) was 93.5 and starch output, 11.16 quintals per hectare, on the average.

Urea ammophos--$CO(NH_2)_2 \cdot NH_4H_2PO_4$, containing 30% of N and P_2O_5. This is a very valuable combined fertilizer. However, it should be produced in granulated form, otherwise it cakes.

Urea phosphate was not inferior to nitrophoska and mineral fertilizer mixtures in 3-year experiments with barley (table 5) and in 4-year experiments with potatoes (table 4).

Ammonium polyphosphates are promising both as solid (containing 10-12% of nitrogen and 62-64% of phosphorus) and as liquid (10% of nitrogen and 34% of phosphorus) fertilizers. Dolgoprudnaya and Ramenskaya agrochemical stations paid much attention to their study (Kartseva, 1970; Yanishevskiy, 1967; Yanishevskiy et al., 1970). Our experiments with Kolelishvili (1973) indicate the same. Gladkova and Cherepanova showed this for potassium metaphosphate as well. Complex liquid fertilizers have already found application in the Lithuanian SSR (Slizhis et al., 1970).

Table 4. Comparative Effectiveness of Urea Phosphate and of Equivalent Mixtures of Simple Mineral Fertilizers in Potatoes Under Conditions of Soddy-Podzolic Soil (Average in 4 Years) (Experiments by A. Peterburgskiy and S. Shafran, 1971)

Fertilizers (60 kg per hectare) N, P_2O_5 and K_2O	Harvest, quintals per hectare		Tuber:top ratio	Starch in Tubers	
	tubers	top		%	quintals per hectare
Control (without fertilizers)	115.9	55.2	2.09	12.7	15.3
Urea phosphate (1:1)+KCl	156.2	70.4	2.22	11.6	19.0
Ammonium nitrate+superphosphate+KCl	162.4	76.1	2.00	12.8	20.5
Urea+superphosphate+KCl	161.4	70.6	2.29	12.6	21.8

The soil taken for the experiment (deep chernozem of Tambovskaya Oblast) was diluted in half with barren sand in order to make the plant reaction to fertilizers clearer.

The doses of nutrients were 0.6 g of N, P_2O_5 and K_2O per vessel with 8 mg of a mixture of soil and sand. Corn developed from 23 July through 20 September. It clearly lagged in growth in the second variant. By harvest time the plants of the first variant had ears that began to form, while by that date the plants of the second variant only blossomed (table 7).

The chemical composition of leaves in dynamics (in % of the dry substance) is shown below (table 8).

These figures indicate that the greatest differences between the first and second variants were in the content of phosphorus. The deviations in the amount of nitrogen and potassium in leaves were negligible. This does not mean that the absolute differences in their removal were also small. Since the harvest was considerably higher in the first experimental variant and lower in the second, the removal of nitrogen, P_2O_5 and K_2O by the plants of the second variant was undoubtedly lower.

The second vegetative experiment was set up by similar methods with the difference that one plant was transplanted into each sector of the vessel. Observations showed that corn developed best in the nitrogen sector. Corn located in the sectors of phosphorus or potassium grew worse than with an even distribution of NPK. The assimilation of phosphorus (in mg per vessel with three plants) was much lower in case of a separate application of fertilizers both at the expense of soil and from tagged superphosphate (table 9).

The data of our experiments on a better utilization of phosphorus, when applied jointly with nitrogen and potassium, by a plant were confirmed in the investigations by A. D. Khomenko and N. I. Moldovina (1964). They noted that the presence of nitrogen and potassium salts in the granule of $Ca(H_2PO_4)_2 \cdot H_2O$ or of nitrophoska increases the amount of phosphorus diffusing in soil and prolongs the distance over which it spreads and, therefore, reduces the amount of phosphorus settling near the granule in the form of dicalcium phosphate. As a result, plants absorb more phosphorus.

The production and application of ammonium and potassium polyphosphates obtained on the basis of polyphosphoric acids, the content of two components in which reaches 80% (and in case of potassium metaphosphate even 100%), are most promising in the future.

Table 5. Comparative Effect of Urea Phosphate, Sulfate Nitrophoska and Simple Mineral Fertilizers on Barley (Moskovskiy-121), on the Average, in 3 Years (Experiment by Peterburgskiy and Shafran, 1971) on Soddy-Podzolic Soil on the Kolkhoz imeni M. Gor'kiy in Moscow Oblast

Fertilizers (60 kg per hectare) N, P_2O_5 and K_2O	Harvest, quin. per hec.		Straw: :grain ratio	Crude protein in grain		Removal by harvest (in total with grain and straw), kg/hec.		
	grain	straw		%	kg/hec.	nitrogen	P_2O_5	K_2O
Without fertilizers	13.8	22.2	1.62	8.6	129.0	32.7	14.1	27.7
ФМ (1:1)+Kx	20.8	27.7	1.33	9.6	224.6	59.8	22.5	36.3
Sulfate nitrophoska	21.4	25.0	1.17	8.9	223.4	46.3	21.5	33.6
NaaPcKx	22.6	31.9	1.41	9.7	243.5	52.0	24.2	42.5
NmPcKx	20.3	28.4	1.40	9.8	232.2	46.8	20.7	37.8

Remark. ФМ--urea phosphate, Nm--urea, Naa--NH_4NO_3, Pc--superphosphate and Kx--KCl.

Table 6. Dependence of Oat Grain Harvest on the Form of Phosphates in Fertilizers (Peterburgskiy and Kalinin, 1959)

Variants	"Frozen" acc. to total P_2O_5	Nitrophoska acc. to assimilated P_2O_5	NPK acc. to assimilated P_2O_5	Carbonate acc. to total P_2O_5	Nitrophoska acc. to assimilated P_2O_5	NPK acc. to assim. P_2O_5
Harvest, quin./hec.	19.5	21.1	21.3	20.1	21.6	23.3
Removal of P_2O_5, kg/hec.	19.5	20.5	21.7	17.9	20.1	22.5

Table 7. Effect of Joint and Separate Application of NPK on Corn

Variants	Weight of dry mass g	%	Weight of dry roots g	%	Total g	%	Phosporus from soil mg	%	Assimilated from fertilizer mg	%
Mixture of NPK	36.2	100	7.1	100	239.4	100	117.4	100	122.0	100
Separately N-P-K	28.3	77.9	3.7	52.1	124.9	52.1	49.5	42.1	75.4	61.8

Table 8. Content of NPK in Corn During Their Joint and Separation Application

Variants	2 VII			22 VIII			7 IX			20 IX		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
NPK mixture	3.0	0.68	2.9	2.9	0.9	2.9	2.3	0.96	2.86	1.28	0.56	2.30
N-P-K separately	3.0	0.63	2.9	3.07	0.69	2.95	2.44	0.47	2.86	1.38	0.37	2.43

Table 9. Harvest of Corn and its Assimilation of Phosphorus During Separate and Joint Application of Fertilizers

Variants	Average weight of dry plant, g	Content of P_2O_5, mg/vessel	Coefficient of Utilization of P_2O_5 from fertilizers, %
NPK	15.0	242.5	17.6
N-P-K separately	21.3-14.2-13.5	211.1	14.9

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