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PART III

NITROGEN IN THE AGRICULTURE OF THE USSR

INCREASING YIELDS AND THE ROLE OF NITROGEN IN AGRICULTURE

The whole history of agriculture in Western Europe gives evidence that the principal condition determining the average yield in different periods was the degree to which farm crops were supplied with nitrogen. There was a thousand-year period during which the three-crop method predominated -- from the time of Charles the Great to that of Lavoisier -- when there was no systematic flow of nitrogen from the outside into farming as a whole, and nitrogen was merely transferred from the meadows into the fields (through hay and manure). But, as the meadows were plowed up with the growth of the population, this source of supply became more and more scarce, and by the 18th Century, yields were stabilized for most of Europe at 7 centners per hectare. Later, when clover began to be grown, toward the end of the 18th Century in England, and even earlier in Belgium and Holland, the crop rotation system was substituted for the three-crop method, and soil was enriched with air nitrogen through clover, both directly through the root remnants and indirectly through the manure obtained by the use of clover hay as fodder. As a result, yields were gradually doubled, becoming in the above-mentioned countries twice as high (15 to 16 centners) as in the Middle Ages.

For a long time no notice was taken of this relative saturation of farming with nitrogen, just as no notice is taken of the air one breathes, until the problem of the importance of nitrogen in the life of plants was explicitly stated by Bussengo. He proved first of all

(1837 to 1838) that the favorable effect of leguminous crops on subsequent crops is connected with their having access to an abundant source of nitrogen, not accessible to grain crops, and, secondly, he established the fact that the most efficient fertilizers for the latter appear to be the nitrogenous ones (guano, liquid discharges by cattle). Although the source of nitrogen available to legume crops was not exactly determined at that time, Bussengo had stated rather definitely even in 1837 the proposition that this nitrogen came from the air. After the supply of nitrogen was increased in the European soils through the use of clover, the positive action of phosphorus on crops began to be evident, although Libich came out preaching mineral feeding, particularly emphasizing the significance of ash elements (especially phosphorus and potassium), without noting the importance of the clover background and thinking that nitrogen comes by itself from the air as NH_4HCO_3. Only the adoption of the system of synthetic cultures (in the 60's of the past century) proved that it was necessary to synthesize the ideas of Bussengo (N) and Libich (PK). "NPK" became a motto in the use of fertilizers, and this was the direction followed in the search for raw materials for the growing fertilizer industry.

Therefore, the new era in agriculture began not in the 40's, when Libich advanced his theory, but 40 to 50 years later, when the development of plant physiology and agricultural chemistry pointed out just what substances are needed by plants and the chemical industry started to supply mineral fertilizers in great quantities and at low prices. At this time the nitrogen of clover was combined with the nitrogen of niter, but it was already necessary to add "PK" to it, while in the past individual crop yields had still been increased by clover nitrogen alone, at least on "clover" soils. From approximately 1885 on, the adoption of mineral fertilizers (on the basis of crop rotation) was gradually increased and came to be widespread.

A new factor appeared at this time which, in not replacing but supplementing the former, strengthened the combined action of clover and manure. Mineral fertilizers take effect in two directions simultaneously: They immediately increase the effective fertility of the soil and, in addition, they raise the quantity and quality of manure. With increased grain crops, more straw is harvested to be used in bedding. With increased sugar beet crops, more beet-tops and pulp are obtained for fodder. Mineral fertilizers and liming increase the clover crop, and with it the accumulation of nitrogen, make it possible to grow clover on soils where it was not formerly grown, and increase the hay harvest and the nitrogen content of the meadows -- all this having its effect on the quantity and quality of manure. In this way the quantity and quality of manure is raised, not only through the influence of clover, but also through the influence of mineral fertilizers.

While at the end of the last century and the beginning of the present one niter played the leading role among nitrogen fertilizers, after the War of 1914-1918 this role was taken over by synthetic ammonia. It followed that nitrogen fertilizers became cheaper still (in the 30's the price of ammonium sulphate fell by as much as 50 percent as compared with the price of wheat), and in the leading European countries yields attained a level three and four times as high as that of the Middle Ages (25 to 30 centners in Belgium and Holland).

At the beginning of this century our yields were 2 to $2\frac{1}{2}$ times lower than yields in a number of Western European countries. In Belgium, Holland and Denmark the average grain yield was almost three times as high as ours. At that time we were inclined to blame this difference on more favorable natural conditions -- climate and soil. But this explanation is entirely incorrect. On the contrary, the soils in the West are by nature worse than ours; their fertility is second rate, brought about by the application of labor and knowledge, and while the climatic conditions of Holland and England do not include the summer droughts of the Trans-Volga region and our severe winter frosts, on the other hand they do not have the sun of Kiev, or even the summer sun of Moscow. In any case, not the climate in the West, but its soil has been made over by human hands, and 150 to 200 years ago, the West with the same climate had the same low yields as prerevolutionary Russia (around 7 centners). Two factors played a role in the alteration of Western soils. They are: (1) clover sowing and (2) mineral fertilizers (including liming), both factors influencing the fertility of the soil directly, as well as through the agency of manure. Clover as a nitrogen-collector, on the one hand, enriches the soil through its root remnants, and on the other, it increases the quantity of fodder, and therefore of manure, in farming. At the same time, thanks to clover, the nitrogen content in forage and manure is also increased.

Since in Western Europe the introduction of crop rotation and of mineral fertilizers were separated by a considerable time interval, about 100 years for England, even more for Belgium, it is therefore possible to measure the effect of one and the other process by the change in the average level of yields over the past 150 years.

The [upward] movement of crop yields in Western Europe, in which nitrogen was the main factor (at first completely, and later for the most part), may be represented diagrammatically by three steps (Figure 33).

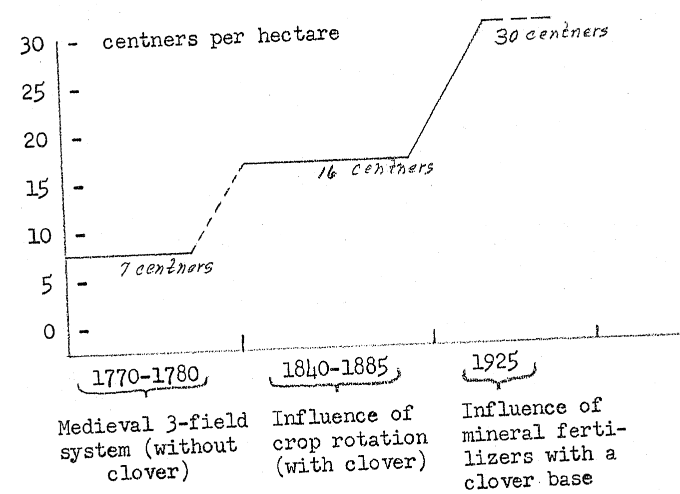

Figure 33. Changes in the level of wheat yields in Western Europe during a period of 150 years (graph).

In corroboration of our graph we can present the following factual information on the progress of crop yields in Holland, Belgium, and Germany.

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Movement of Yields in Holland, Belgium and Germany

(In Centners)

Countries	I 3-Field Period (Middle Ages)	II Period of Crop Rotation 1840-1870	1880	III Influence of the Introduction of Mineral Fertilizers 1891-1900	1909-1913	1926-1930	1936-1938
Holland	7	15.5	17.7	19.4	22.5	29.8	31.8
Belgium	7	15.0	15.3	19.3	25.3	25.5	28.5
Germany	7	13.0	14.0	17.4	22.7	(19.9)	24.3

From this it can be seen that the change alone from the three-field system to crop rotation with cultivation of clover and root-crops had gradually resulted, over a number of decades, in <u>a doubling of yields</u>, which, against the medieval level of 6 to 7 centners, had risen to 13 to 17 centners. They remained stable at this level for a long time, and only later, under the influence of the introduction of mineral fertilizers, did a new wave follow of even greater and swifter increases in crop yields -- up to three and four times as high as the original level (7 centners). This trend began in the 80's and continued increasing with an interruption at the time of the First World War, especially for Germany. (We see that Belgium and Holland kept pace with each other in increasing yields up to 15 centners, but beyond that a difference may be observed in favor of Holland, -- and this is because Holland, participating with England in supremacy of the seas, began using Chilean saltpeter before Belgium did, and besides, by creating a network of dams and canals, Holland secured cheap water transportation of night soil from the cities to the fields.

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Germany, by comparison with her Western neighbors, was late in introducing grass-sowing, so that only in the middle 80's did she attain such yields as Belgium already had in the 40's of the past century.)

Malthus had not foreseen this when he assumed that the growth of agricultural production would lag behind the growth of population. It is essential to add that the general growth of production effected by the conversion of crop rotation could not be attributed to the growth of grain yields alone. The fact was that the introduction of [cultivated] row-crops on 25 percent of the acreage operated to the same effect, since potatoes yield a production of dry matter per hectare three times as high as grain-crops, and root-crops with very high yields base may yield even more. Besides, the elimination of fallow, which under the three-crop system occupied 33 percent of the arable area, increased the sowing area by 50 percent. If all this is taken into account and the yield for all crops is translated into grain equivalents, the growth of production per hectare of sowing area under the conditions of Belgium and Holland is as follows (in centners per hectare):

	Food Value Grain Equivalents	Ditto Including Fodders
Under the 3-crop system.............	4.3	5.9
Under crop rotation (before the introduction of mineral fertilizers	19.0	29.0
Ditto, after the introduction of mineral fertilizers................	38.0	52.0

(In this conversion, 1 centner of wheat and rye represents 1 unit, the yield of oats is divided by 1.2, that of potatoes by 4, roots by 5, clover hay by 2.5, oat straw by 4, and rye straw by 5.)

In this way the growth of production went on at a rate close to the ratio of the squares 1^2: 2^2: 3^2; i.e., fourfold and ninefold, and not as Malthus had thought (in arithmetical progression). In calculating the rate of increase of population Malthus made the converse error, strongly exaggerating this rate. (In Malthus' time the population growth in England was 13 per 1,000, i.e., close to the Russian growth during the period 1860 to 1914, which corresponded to a doubling of the population in 50 years, while America's population doubled in 25 years (but immigration also contributed to this). Even France had a gain of 9 per 1,000. But one hundred years after Malthus, France's population growth decreased to 0.6, almost coming to a stop (and it was not the poor people, but the bourgeoisie that pioneered in the conversion to the "two children system"), while agricultural production in France can still be greatly increased. Germany, during the period 1885 to 1914, was an example of production growing more rapidly than the population. In the United States, where they did not know what to do with surpluses of wheat and corn, population growth was gradually decreasing. It is twice as low as in Poland, Yugoslavia and Bulgaria and, according to statistical calculations, by 1970 the number of births and deaths should be equal, i.e., the US will find itself in France's situation with respect to population growth, in spite of the fact that the means of food production in the US are greater than anywhere else.) But all this need not be argued in detail, since it turned out that in the capitalistic countries crises result not from a shortage of products, but from over-production.

That the rapid rise of crop yields at the end of the 19th Century was mainly caused by mineral fertilizers follows from the fact that in other respects there were no other significant changes in this period (i.e., during the period when Europe took the path of chemistry, America took that of mechanization, but its yields remained at the previous level.)

At the end of the 19th Century nothing new happened in Belgium and Holland, either in the field of soil treatment or that of [plant] selection. Nor did crop rotations undergo any new changes. In effect, mineral fertilizers were the only new factor affecting crop yields during this time, but they, of course, also heightened the importance of previous factors -- clover and manure.

It is precisely to this period that K. A. Timiryazev referred in his statement when he said that European agriculture became what it is solely because of agricultural chemistry and plant physiology.

The mechanization of agriculture in Europe was then insignificant, except for the introduction of reapers, but reapers do not increase crop yields. The United States was the center of development of mechanization, but the process of increasing crop yields, characteristic of Europe, did not take place there. In general, mechanization is above all a means for the encompassment of wide areas in countries where labor is expensive; it directly decreases the amount of labor for grain growing, while the application of chemistry decreases such expenditures by the fact that yields are increased while the amount of labor per hectare remains practically constant. These correlations between the significance of chemistry and mechanization may be illustrated by the following table:

	Yield (Centners per Hectare)	Index of the Application of Chemical Fertilizer ($N-P_2O_5-K_2O$ in kgs per Hectare)	Index of Mechanization (Number of tractors per 1,000 sown hectares)	Density of Population
Holland	30	109	} 1	217
Belgium	27.5	89		257
Japan	27	75		157
Germany	22	67		138
France	15	22		75
United States	9	12	10	13
Uzbekistan	17	106	8	--

If we turn to our own conditions, it will appear that the problem of nitrogen played an important role in the development of our own agriculture as well, and in practice the cheapest ways of solving it were unconsciously sought for, -- only originally in our country the main role was played not by clover nitrogen, but the nitrogen of the chernozem soil /black soil/.

As soon as the southern steppes were safe from the invasion of nomads, they became the goal of a spontaneous peasant colonization, attracted by the possibility of not having to expend energy on grubbing and of obtaining, without recourse to manure fertilization, good yields of bread grains at the expense of the abundance of nitrogen in the chernozem soil; -- true, these yields were not at all very high and always unstable, but cheap bread was obtained from them. (The frequent alternation of years of high yields and drought years of low yields led to the fact that the highest average yields were /obtained/ in the Baltic region and in the North (Shenkurski Uyezd), while the Orenburg, Samara, Tavricheskaya Guberniyas and Voyska Donskogo (Don Cossack) Oblast' were characterized by lower averages.

Nevertheless, thanks to the large sowing areas and sparse population, the South served as the supplier of bread for the North.) Besides, not only was the plowing area in the South growing more and more, but also the land for plowing in the North was shrinking in proportion to the development of railway communication with the South.

If we do not concern ourselves with the shrinking of the plowland on the landowners' estates in the North as a result of the abolition of serfdom, but consider the subsequent period, when peasant acreage predominated on the non-cherozem soil strip, its systematic shrinking can still be noticed. For example, in Moscow Guberniya, rye sowings in 1864 occupied around 400,000 hectares, in 1900 -- around 220,000 hectares, and in 1916 -- only 150,000 hectares (while the total plowland area decreased from 1,200,000 hectares to 460,000 hectares). Meanwhile the chernozem soil strip was being plowed up more and more, the land along the Volga yielded durum wheat grain rich in albumen, and manureless farming reigned for a century. In 1830, around Khar'kov, the employment of manure was still considered harmful, and when manure was called for, it acted initially through its phosphorus, and not its nitrogen. Thus, the Khar'kov Station at the beginning of the 20th Century had observed gains of 50 poods in the yield of winter rye both equally from the application of superphosphate and from manure, and no gain at all from saltpeter. True, this was only for bread grains, and winter grains at that, coming after nitrate-rich black (bare) fallow, although sugar beets had already shown a demand for nitrogen. The sugar beet's demand for nitrogen had previously been met by the fact that it, too, was planted on black (bare) fallow (an unprecedented occurrence in non-chernozem soil Western Europe), although later (at the end of the 19th Century)

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saltpeter began to be applied also with respect to it, while in the 20th Century bread grains also began to respond to nitrogen. Thus clover, as also in Western Europe, turned out to be a wonderful predecessor for bread grains (experiments at the Nosovskaya and Sumskaya stations). Thereupon, direct experiments by the NIUIF (Research Institute of Fertilizers and Insecto-Fungicides Under the People's Commissariat of Chemical Industry of the USSR) network [of stations] managed by Lebedyantsev, showed that spring bread grains on black soil responded strongly to nitrogen fertilizers. Thus the period of "nitrogen Eldorado" began to draw to a close, so that for the black soil region, at least in its western section, it became necessary to adopt the same measures as in the northern non-black-soil strip (clover and manure for bread grains, and a still considerable amount of nitrogen fertilizers for industrial crops) for a solution of the nitrogen problem.

Surprisingly, the role of nitrogen in the agriculture of the non-chernozem-soil zone was not immediately appreciated in full measure: The reason for this was the fact that experiments were based on the economics of current production, instead of considering the state as playing a role in the organization of future production. Thus, when the agronomists of the Moscow Zemstvo, under the influence of Timiryazev and Chuprov, decided (in 1908) to begin experiments with mineral fertilizers on peasant lands, in these experiments they either would not apply saltpeter at all, or they used it in insignificant quantities, as a sort of stimulant, reasoning that imported saltpeter (from Chile) was too expensive for peasants to buy, i.e., they confused scientific research goals with propaganda for the use of saltpeter. For this reason mineral fertilizers did not yield the expected result, which was incorrectly attributed to the unfavorable physical properties of our soils, and reference was made to England, where a whole century went by between the introduction of grass sowing and of mineral fertilizers, and therefore, it was claimed, to introduce the latter here would also be premature. The same mistake was repeated later, too, namely, in the 20's. The leadership of the People's Commissariat of Agriculture of that time did not give experimental stations the means to set up experiments with mineral fertilizers, "because the peasant does not ask for them".

But even in those individual cases where experimental stations did set up experiments according to the eight [stage?] plan, they followed the example of the first experiments of the Moscow Zemstvo (1908 to 1912) and put in only 15 kilograms of nitrogen, with 40 to 50 kilogram doses of phosphorus and potassium. (It was just these doses that proved to be the most unsuitable on poor soils (see below)). I was able to verify this on a tour of the experimental stations in the Ural and Volga regions in the fall of 1926, and of course, as compared with manure, into which 150 to 200 kilograms of nitrogen were introduced, the effect of mineral fertilizers was weak. (By the way, results of the experiments were briefly reported to me at the Kazan' Experimental Station in the following form: "We are not getting any results either by the Pryanishnikov or the Doyarenko methods", i.e., neither mineral fertilizers nor fallow cultivation were of any help. "Manure is the only thing that has any effect". Upon having acquainted myself with the fertilizing doses, I advised that the nitrogen quantity be increased. After two years, in 1928, when the periodical Mendelian Congress took place in Kazan, new data from the Kazan' Station were included in the reports of the agricul-

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tural-chemical section in which the action of mineral fertilizers no longer differed in extent from that of manure.) This gave me the opportunity to write in the spring of 1927 an article entitled "Chronic Error of Evaluation When Determining the Effect of Mineral Fertilizers," and that year turned out to be the turning point in the setting up of experiments with fertilizers, for it was then that the Agricultural-Chemistry Department of NIUIF, which I headed, organized the so-called "geographical network of experiments". The data of these experiments gave immediate evidence of the fact that where the same doses of nitrogen as in the West are applied in the region of podzolic soils and on the serozems of Middle Asia, the same effect is obtained (experiments with cotton, flax, and potatoes). Moreover, it appeared later on, that industrial crops also respond to nitrogen on the Chernozem soil (such as sugar beets and hemp), but grains also definitely respond to nitrogen, where they do not follow bare fallow. All this made it possible for the chemical industry to set up a plan on a large scale and to start carrying it out in the First Five-Year Plan. During the Second Five-Year Plan, data of the VIUAA (All-Union Scientific-Research Institute of Fertilizers, Agricultural Soil Science, and Agrotechnics Under the People's Commissariat of Agriculture USSR) showing that the use of mineral fertilizers gives good results, not only on the experimental fields, where the experiments of the NIUIF were set up, but also in conjunction with the agricultural techniques that were already in use in 1932 to 1934 on the fields of collective and state farms. Thereupon the Stakhanov movement, in its powerful development, showed so clearly the importance of fertilizers, that hardly anyone would maintain that we should first go through some other stages before coming to the application of mineral fertilizers. It is characteristic that record crops obtained by the Stakhanovites coincided with the period when the production of mineral fertilizers in our country became large-scale.

We must, of course, take into account the historical development of agriculture in Western Europe, but this does not at all mean that we must, as some have thought, go successively through all the stages which took place there. (It was maintained that first we had to introduce grass-sowing, go through a stage of pure manure farming, in order to improve the physical properties of the soil, and only then consider using mineral fertilizers. ("Why, in England they started using mineral fertilizers 100 years after the introduction of grass-sowing"). Besides, an incorrect account was often given of the history of agriculture in Western Europe, and the fact was concealed that it was not the field-grass rotations, but a pure crop-rotation system, utilizing a one-year sowing of clover without timothy which had first led to a doubling of crop yields in the West and later to their further increase after the introduction of mineral fertilizers.) Our task consists in catching up with and surpassing within a short period of time the economically advanced capitalistic countries, and we can and must do this, availing ourselves simultaneously of all the possibilities which are at the disposal of a systematically developing socialist agriculture, and not slavishly imitating any ready-made patterns.

STRUCTURE OF THE NITROGEN BALANCE IN DIFFERENT COUNTRIES

SYNTHETIC AND BIOLOGICAL NITROGEN

The rapid development of the nitrogen industry after the first World War caused non-agricultural circles to think that this factor crowded out all others and that it was mainly responsible for the high crop yields obtained in countries with a highly developed nitrogen industry. But, in practice, nowhere did the new sources of nitrogen (synthetic ammonia, calcium nitrate, etc.) replace clover nitrogen and manure nitrogen; in all cases they re-supplemented the earlier-known procedure and increased the total amount of nitrogen introduced into the farming cycle, thereby raising to an even higher level those yields which in Western Europe were already rather high, thanks to clover-sowing with simultaneous use of phosphates and potassium salts.

In all the Western countries they are even now continuing to proceed by complex means, with two methods being utilized for fixing air nitrogen, namely, the technical method, feasible with the help of expensive equipment only in specific places, where there are concentrated sources of energy (coal deposits, waterfalls), and the biological method, practicable everywhere because it utilizes solar energy and requires no equipment, but uses instead clover, lucerne and other nitrogen-collectors which fix the air nitrogen with the same source of energy that aids them in fixing carbon.

Both methods of solving the nitrogen problem have their positive aspects and their difficulties; they mutually supplement one another but cannot completely replace each other. Synthetic nitrogen is characterized by: (1) very swift action in connection with the solubility and high assimilability of synthetic factory products (making possible a rapid tempo of yield increase); (2) easy transportability related to the high concentration of nitrogen content (for example, in synthetic urea there is a hundred times more nitrogen than in manure), and the possibility of transporting it to any locality at will; (3) the possibility of considerably greater saturation of the crop rotation with industrial crops ta than in the absence of synthetic nitrogen (thus, we could not devote to cotton for a long time such a large percentage of the area in Middle Asia if the cotton-growing regions were not mostly supplied with nitrogen fertilizers); (4) at the same time the large-scale nitrogen industry develops for other reasons too besides the agricultural ones -- above all it is connected with the war industry.

But synthetic nitrogen is always more expensive than manure nitrogen, and therefore even in countries with a highly developed industry the main role in supplying agricultural plants with nitrogen is not played by synthetic nitrogen but by biological nitrogen since the nitrogen of clover hay is transferred to manure. In effect, the biological method of fixation of air nitrogen costs nothing where all the expenses of clover or lucerne cultivation are paid for by livestock-raising. Nevertheless biological nitrogen with the indisputable advantage of cheapness has its shortcomings in comparison with synthetic nitrogen; it is not transportable and is very slow-acting, and, of course, it cannot be directly utilized for defense purposes. We point out, however, that the more clover

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sowings there are in the country, the richer it is in livestock and manure, the less would bread-grain yields be affected in a drawn-out war by a lack of technical nitrogen.

The quantitative relation between both nitrogen sources, of course, is different in various countries; and in principle, if there were no causes of a military-political order, it should depend in the first instance on the density of population: namely, the greater the latter, the larger the percentage of acreage that would have to be occupied by food crops and the smaller the area that could be occupied by fodder crops (and among the latter the first place is taken precisely by nitrogen-collectors). In this connection we have the greatest possibility of expanding the area under nitrogen-collectors (at the expense of enlarging the plowing area), but within the limits of Western Europe a significant variation may be observed in contiguous countries. Let us compare, for example, industrial Germany with agricultural Denmark; Germany having (before Hitler) a high level not only of industry but of agriculture too -- much higher than in France. Denmark has no raw material for developing its industry; livestock products take first place in its exports; and it is considered primarily an agricultural country although in effect the peasants constitute only one third of the total population of the country. The principal difference which is of interest to us in this particular instance is the fact that Germany had 133 persons per square kilometer and Denmark, 80; and this difference will be still more apparent if we take into account the fact that the share of sowing area per person in Denmark reached as high as one hectare, while in Germany it was just about one third of a hectare (see below). Consistent with this we find in Denmark a much larger portion of sowings under clover mixtures than in Germany, and therefore more manure per hectare of plowland -- manure, moreover, which is richer in nitrogen than usual, owing to extensive use of concentrated fodders of import origin. Germany, having a highly-developed chemical industry, made use of synthetic products (ammonium salts, cyanamide, calcium nitrate) as a source of nitrogen on a larger scale than Denmark. Nevertheless, even with the nitrogen factories reaching their highest production, this source of nitrogen was relatively not in a dominating position; in Germany the principal role was played by the organic matter of manure and clover, as can be seen from the following comparison.

Nitrogen Balance	In 1,000 tons: Germany	In 1,000 tons: Denmark	In Percentages: Germany	In Percentages: Denmark
Nitrogen used up by crops	1775	270.0	100.0	100.0
Sources of Compensation:				
Synthetic Nitrogen . . .	400	27.0	22.5	10.0
Manure nitrogen, including part of clover nitrogen	750	150.0	42.2 } 56.7	55.5 } 81.1
Nitrogen in the root remnants of leguminous plants	256	69.1	14.5	25.6
Deficit	369	24.0	20.8	8.9

(For Germany we made use principally of Lohnis' previous computation but with certain corrections to bring it closer to post-Versailles conditions, namely: the amount of manure has been computed according to livestock conditions during the pre-crisis period (Statistiches Jahrbuch f. d. Deutsches Reich); and, similarly, more recent figures were taken for the amount of nitrogen fertilizers than those used by Lohnis; for the nitrogen used up by crops, as well as for the nitrogen in clover root remnants, Lohnis' figures were used without modifications.

For Denmark we made the computation on the basis of data in the symposium L'agriculture en Danemark (1930). For manure the average nitrogen content was used in view of the difficulty of making a correction for the increased influence of the extensive use of concentrated fodders in Denmark. Nitrogen brought in by precipitation is not taken into account anywhere on the assumption that the nitrates washed out of the soil are equal to this source of intake.)

Consequently, even in such an industrial country as Germany, the nitrogen industry did not meet even one fourth of the total demand for nitrogen. In more agrarian Denmark, rich in clovers, and therefore also in manure, technical nitrogen constituted only 10 % of the total nitrogen used up by crops. A converse relation, of course, is true for the nitrogen of clover plants, which in Denmark plays a much greater role. But in both countries manure nitrogen takes first place; it covers more than half of the total nitrogen withdrawn by crops in Denmark and 42 % in Germany. These

Nitrogen Balance in the Agriculture of the US (as per Lipman)

(in 1,000 tons of Nitrogen)

Loss		Gain	
Removal of nitrogen by crops (from an area of 146 million hectares)	4600	Nitrogen supplied by manure	2600
Washed out by precipitations	4000	Nitrogen supplied by mineral fertilizers	300
Erosion (from the same area)	2500	Added through precipitation	2750
Removal of nitrogen from meadows and pastures (400 million hectares)	3000	Left by irrigation waters	30
Washed out from this area	1000	Accumulation of nitrogen through leguminous plants	900
Erosion	1000	Fixation of nitrogen by other means	6800
Total	16,100	Total	13,380

The deficit which must be put down to the account of the consumption of nitrogen out of the basic /nitrogen/ capital in the soil consists of 2720 thousand tons of nitrogen, or 16.9%. But since in Dr. Lipman's article ("The Stuff of Life", reprint from Industrial and Engineering Chemistry, vol 27, p 103, 1935) no indication is given of how the individual components were calculated, we cannot take these figures as directly comparable with those presented above for Germany and Denmark. Our attention is drawn particularly to two figures -- i.e., the high estimate of manure nitrogen's share in the total balance (it is 56.5% of the nitrogen withdrawn by crops) and the even higher share of nitrogen fixed by other means (beside leguminous plants). But if this figure is in general hard to determine, the accumulation of nitrogen by leguminous plants lends itself much more easily to computation, and it is interesting that according to this article we find the figure for the nitrogen withdrawn by crops to be 900 thousand tons, or almost 20% of the total.

Granting provisionally the possibility of comparing the various forms of intake and outlay of this calculation for the US with the calculation presented above for Denmark and Germany, and taking only the corresponding headings, we obtain a picture of a simplified balance for the US as follows:

Removal of nitrogen	4600 thousand tons, or	100%
Supplied by manure	2600 thousand tons, or	56.5%
Supplied by mineral fertilizers	300 thousand tons, or	6.5%
Fixation by leguminous plants	900 thousand tons, or	19.6%
Deficit	800 thousand tons, or	17.4%

As may be seen, the share of synthetic nitrogen in the total balance for the US results somewhat lower than for Denmark and Germany, being only 6.5% of the nitrogen withdrawn by crops. On the whole, then, the nitrogen returned to the soil with fertilizers is more than 80% of that withdrawn by plants.

The calculations made by us on the nitrogen balance in the agriculture of the USSR present a completely different picture. For the time being we shall consider only the general character of this balance in the form that it actually took during the prewar years.

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The total amount of nitrogen withdrawn by crops, as computed by the VIUAA for 1937, was in this country approximately 4.9 million tons (with a grain yield of nearly 10 centners per hectare, beets 200 centners per hectare, potatoes 115 centners per hectare, etc.).

The restitution of nitrogen to the soil was effected here too, not only and not so much with mineral fertilizers as with manure, with the organic mass of nitrogen-collectors, waste products (excrements) and peat.

How much of this removal of 4.9 million tons of nitrogen was returned by manure?

Assuming that in 1937 nearly 200 million tons of manure were taken out, we obtain 1 million tons of nitrogen. As for the root remnants of clover and lucerne, we can assume that they left in the soil around 200 thousand tons of nitrogen (the nitrogen of the parts above the ground should not be counted separately here; it was already included in the make-up of manure.)

Industry, too, in 1937 was producing around 200 thousand tons of nitrogen. Counting utilization of waste products (peat-excrements), we may allow the restitution of 100 thousand more tons of nitrogen. Thus, only about 1.5 million tons were returned, which is 30.65% of the total removal (4.9 million tons), while the deficit equals 3.4 million tons, or 69.35%.

This deficit was covered in this country mainly at the expense of the nitrogen supply in the soil (nitrates of fallow fields, autumn plowing etc.).

Let us now compare the nitrogen balance with what took place in the Western European countries, which went through the process of raising yields from the Middle Ages level (7 centners per hectare) to the present one (22-28 centners per hectare), and in the US (see Table).

From this comparison it is apparent that the characteristic trait of our nitrogen balance consists in the presence of a much larger deficit reaching almost 70%, while the Western countries had a much smaller nitrogen deficit lying within the range of 9 to 21%.

How was this relative deficit in nitrogen made up in the West, where fallow fields had disappeared and the rate of soil depletion became incompatible with the problem of a steady increase of yields? The German microbiologist Löhnis was inclined to attribute the main role here to the action of free-living bacteria (not tubercle) of which the most prevalent in cultivated soils is Azotobacter, but it is not easy to take into account the degree of fixation of nitrogen by this method. Under this heading fall, in part, some sources of nitrogen not fully accounted for, such as the nitrogen of waste products -- composts, etc., or the portion of nitrogen supplied by atmospheric precipitation (assuming that the leaching out of nitrates by these same precipitations does not altogether offset this source of supply when the soil is occupied by plants whose roots energetically absorb the nitrates).

In any case, the fact is that a deficit of such degree as occurs in Germany and Denmark was not made up through soil depletion since their crop yields not only did not decrease, but, on the contrary, were at this time much higher than 40-50 years before.

This means that a deficit of 20-21% (or, in absolute figures for Germany, 13-14 kilograms per hectare), according to the given method of computation, does not present any danger. We shall take this circumstance into account later when we determine our nitrogen balance for the future.

Furthermore, as has already been pointed out, even in countries such as Germany with a highly developed industry, the nitrogen industry did not play the role of principal supplier of nitrogen. The main role belonged to biological nitrogen, i.e. to manure nitrogen, including the nitrogen of the above-ground portion of clover and to the nitrogen of clover root remnants. In Denmark these two sources taken together compensated for 81% of the nitrogen withdrawn by crops and in Germany -- 56.7%. Although possessing the most land, we have until now taken absolutely not enough advantage of the possibility of expanding clover and lucerne sowings, as may be seen from the following comparison:

Countries	Percent of Sowing Area Under Nitrogen Collectors	Hectares of Total Land per Inhabitant	Sowing Area: Per person of total population (in hectares)	Sowing Area: per person of rural population (in hectares)
Germany .	10	0.74	0.30	1.3
France. .	20	1.35	0.53	1.3
Denmark .	32	1.25	0.90	3.0
USSR . . .	4	14.0 *(see next page)	0.80	1.2

* If we take off 50 percent of the acreage for unusable land (deserts, tundras, mountain ranges, glaciers), we still have 7.1 hectares of usable acreage per inhabitant.

While industrial Germany, though suffering from lack of sufficient land to provide itself with indispensable agricultural products, was nevertheless able to put 10 percent of the acreage under nitrogen-collectors, we were devoting to them only 4 percent of the total sowing area in our country. (Let us note that this figure is not stable; in /some/ individual years the percentage of land under clover fell even lower, while with the introduction of correct crop rotations it should rise considerably.)

Industry, as previously stated, compensated in Denmark 10 percent, in Germany 22.5 percent, of the total nitrogen depletion. This is readily understandable when we consider that German industry, as that of the United States and our own, produced on the order of 200-400 thousand tons of nitrogen, while nitrogen removal in crops is measured in millions of tons.

Let us return, however, to the nitrogen balance of the USSR. As we have seen its main item is utilization of chernozem nitrogen which in the southeast still makes it possible to farm so far on a negative nitrogen balance basis, but in areas of age-old cultivation (Northern Ukraine, Kursk and Voronezh oblasts) even the chernozem now requires a return of removed nutrients. This shows that we cannot delude ourselves by assuming that the major portion of the tremendous deficit is compensated 69 percent by Azobacter activity; and an agricultural system wherein only 31 percent of the nitrogen is returned to the land cannot ensure crop yield increase.

Even on making the improbable supposition that our crop yields are based not on a gradual depletion of chernozem but wholly on Azobacter activity, this would only constitute a system in equilibrium and not a means of increasing the yields. If, however, we wish to produce in lieu of 5 billion poods of cereal grains, 7-8 billion, and to increase in proportion yields of industrial crops, this amounts to a 50-60 percent increase in nitrogen removal while to raise depletion of nitrogen by 2.5 million tons it is necessary to make it good in fertilizers (and in clover) to a considerably greater extent.

While it is true that for a certain length of time, some increase of winter grain crops yields can be attained in the chernozem areas by better utilization of early-fallow nitrogen on incorporation of phosphates, in the long run it is not possible to withdraw nitrogen continuously from the soil without any return; and furthermore this does not solve the problem of spring crops, especially industrial crops. Hence, it is indispensible to increase nitrogen intake by way of industrial nitrogen fixation, as well as by means of greatly expanding cultivation of nitrogen fixing crops.

The acute nature of the deficit existing between removal of nutrients by crops and return of nutrients by fertilizers, with the major portion of the removal made up not by an addition of fertilizer but at the cost of exhausting the nutrient resources of the land, is incompatible with the task of steady yield increases.

We still do not appreciate sufficiently to what extent our agriculture lags behind industry in the rate of reorganization. It has merely undergone modification in its superficial mechanical methods, but the essential cycle of substance exchanges in agriculture has retained the old, prerevolutionary nature. The major part of nutrients utilized by the plants and removed in the crops is still not being returned by fertilizers, and yield is obtained primarily by exhausting the land; whereas western countries, in order to attain a three to four fold yield increase over those produced in the Middle Ages, have long since been compelled to revise the nitrogen balance and to return 80 percent of the nitrogen removed by crops (as well as 100 percent and more of the phosphorus).

In any event, on considering the nitrogen balance system, it becomes clear that to obtain consistent yield increases, ensure their stability, and raise fertility of our soils, it is necessary to strive for a drastic change of this balance along lines which enhance credit items, and this is necessary not only to lower the present deficit in the balance of nitrogen, but also to ensure compensation of still greater nitrogen removal in future crops.

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OUTLOOK AND PROBLEMS OF NITROGEN BALANCE AMELIORATION IN THE AGRICULTURE OF THE USSR.

On passing from the analysis of actual nitrogen balance status to the problem concerning prospects of its future amelioration, it is necessary to try, first of all, to determine, if only approximately, the magnitude of nitrogen removal by crops, which in itself would resolve the problem of catching-up with and outstripping economically the leading capitalist countries.

To do this we must specify what we propose to consider as the problem of catching up with and outstripping the West in the domain of agriculture. Can the problem be considered as being that of attaining an average yield per hectare, equal to or exceeding the average yield produced in West-European countries?

This question must be answered negatively. The problem cannot be solved by mere comparison of yields, and the goal is not, for example, to overtake Holland and Denmark in average yield level - (30 centners per hectare) for the entire country.

We must find <u>our own</u> approach to the determination of yield level, so as to know how much acreage should go under cultivation.

Naturally, it is not only the yield per hectare, but acreage under cultivation as well, that are the factors upon which depends the rate of supply by agricultural products of a country. The following comparison (see Table below) is sufficient to show that yield per hectare gives but little information relative to the magnitude of this supply.

Countries with Grain Deficit	Wheat Yield in Centners per Hectare	Countries with Grain Surplus	Grain Yield (in Centners per Hectare)
Holland	29.1	Argentine	8.7
England	22.5	Canada	11.8
Germany	21.5	United States	10.9

(Average yields over the 1930-1934 period)

It can be said in general that the highest yields per hectare are characteristic of densely populated, land-poor countries which import grain, while countries having surplus grain and exporting it, produce much lower yields per hectare, but do have plenty of land and considerable areas of cultivation per capita.

In our case both routes are open toward an increase in overall production, and, in contradistinction to Western Europe, we are free to adjust either factor in increasing our production, since the acreage under cultivation constitutes but 7-8 percent of the total area of the USSR, or approximately 15 percent of the arable land, on excluding that which consists of tundra, desert, crags, and glaciers.

Computation of total production, which is the result obtained on multiplying the yield level by the acreage under cultivation, must always include determination of the ratio of total production to number of inhabitants. This was frequently overlooked, especially in earlier prerevolutionary days, through captivation by the huge value of total yield (" we can swamp Europe"), in lieu of taking into account the total obtained per capita. Actually, such calculation shows that even during the so-called good years, when Russia exported grain abroad, it produced in fact no more than many of the Western countries importing our grain, as is apparent from the following tabulation of data covering the period 1908-1913.

Production of Grain (All Varieties) per Capita (in Centners).

Russia	4.0	Exporter
France	4.3	
Germany	4.6	Importers
Sweden	5.0	
Denmark	7.0	
United States	10.3	
Argentina	10.0	Exporters
Canada	19.0	

It is known that the ability of Russia to export grain depended solely upon the fact that the Russian peasants were involuntary vegetarians and forbore from fattening hogs, while in Germany and Denmark our grain was extensively utilized for this very purpose.

What production level per capita is then desirable in our case? Let us consider the production of grain.

We shall start with the assumption that a necessary foundation is provided by a liberal fulfillment of the needs in food and feed grains, of the growing population within the Union, fully taking into account yield deviations from the average due to inconstancy of climatic conditions, but that development of grain export is not one of our immediate problems. (Danish and American practice has shown that when an excess of grain exists for a country, it is more advantageous not to export the grain as such, but the animal products obtained therefrom, such as butter, eggs and bacon.) We can thus postulate as a goal the provision on the average of 8 centners of grain of all kinds per capita of population, which in normal years would provide 4 centners of grain for animal feed, in addition to a steady minimum of 4 centners of food grain per inhabitant. Obviously, delimitations between food and feed grain are not strict ones. Grain of value as food, such as rye, is used as feed if available in excess, whereas feed grain (barley, corn, oats), becomes food when a harvest is poor. It is all a matter of quantity available. The 8 centners figure exceeds two-fold the prerevolutionary level of our production per capita and is intermediate between Danish production (the highest in Europe), amounting to 7 centners per capita, and that of the United States.

Although Denmark is listed among the importers, it is essentially an exporter. Originally it did export grain, but subsequently ascertained that it was not worthwhile to deal in such a cheap commodity and began to convert grain into bacon, butter and eggs, and also to buy foreign grain for the same purpose. Thus, the Danish crop-yield per capita is a very good one, but the climate of Denmark is very stable, while we require additional provisions to meet the eventuality of poor crops due to climatic fluctuations. On the other hand, the United States, with its production of 9-10 centners per capita, was in a position to conduct on a large scale both stock-feeding and grain export to Europe. The proposed average production level of 8 centners per capita includes provisions made to meet the conditions of exceptionally dry years, when hog feeding must be reduced (This level corresponds, taking into account the size of our population in 1939), to the goal of producing 8 billion poods of grain set by Comrade Stalin in his report to the 18th Congress of VKP (b). Of course this is the immediate aim, and subsequently we must further increase grain production, bearing in mind not only a direct increase of grain consumption for food purposes, but also the necessity of greatly increasing grain production for use as feed.) during average years, and the more so in good years, it would permit export or a possible increase in such export of grain, if necessary, or the utilization of this surplus for industrial processing and increased production of animal products suitable for prolonged storage (cheese, hams, smoked sausages, etc.). (If, following a bumper crop season, the 2-centner surplus of grain per capita is used for export, the total amount would exceed 40 billion tons, which is four times more than the maximum export attained under the Tsars.)

Assuming that in lieu of the 185 million population of the 1939 census, the USSR were to compute 230 million people, then according to the proposed scale, 184 million tons of grain would be required. To what yield per hectare does this amount correspond? In answering this question we must take into consideration the following:

Total production can be raised to 184 million tons in three different ways:

A. By producing on the present acreage devoted to grains (about 110 million hectares) a higher average yield of 16 centners per hectare without expanding the acreage under cultivation.

B. By increasing the grain producing area while maintaining a lower yield; for instance, by producing a 14-centner yield over an area of 130 million hectares.

C. By expanding the area under cultivation not for the production of grain crops, but for an increase in the acreage under clover and other nitrogen fixing plants, so as to develop livestock raising, obtain more manure, and increase yields of grain crops on the present area (about 110 million hectares) of their cultivation.

Let us consider each of these cases separately.

Due to the small percentage of acreage under nitrogen-fixing plants, and the correspondingly lower availability of manure supply, in order to attain an average yield of 16 centners grain per hectare on the present area of cultivation (variant A), it would be necessary to use large amounts of mineral fertilizers for the production of grain crops in order to compensate deficiency in nitrogen and other nutrients induced by inadequate manuring and the small role of clover and other legumes in the nitrogen balance. But application of mineral fertilizers to grain crops on a large scale is a difficult project <u>for two reasons:</u> (a) the area under industrial and other crops requiring intensive cultivation in our

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Hence, since the first of the three above-indicated variants, (A), is found to be the least suitable, we could not adopt such a course.

The second method (B), would make it possible to forego application of mineral fertilizers, at least of nitrogen fertilizers, to grain crops; but it would be more acceptable if there were to be used the old source of power, horses (or oxen), rather than the tractor. The latter requires additional yearly expenditures for fuel and fuel transportation, which are more difficult to meet precisely in those areas best adapted for expansion of land under cultivation (in Siberia).

The third variant (C) does not require an annual increase of tractor operations, inasmuch as an acreage expansion of 25-35 percent needed for planting of forage crops would necessitate but <u>one</u> plowing (on first utilization of new areas) of the land, since areas under forage crops need not be plowed every year. Further development of this variant must be coordinated with the <u>problem of livestock development</u>. This variant deserves most consideration, but there are possibilities of combining it

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with a partial utilization of variant B.

In summarizing what has been said before, we arrive at the conclusion, that essentially we must adopt the course of increasing grain production by raising the grain yields to about the 16 centners per hectare level and utilize to a lesser extent, in the near future, the expansion of acreage under grain cultivation for the attainment of this goal. A total expansion of plowland should thus afford the possibility of increasing primarily the percentage of our cultivated land devoted to clover and other nitrogen fixing crops without decreasing the area used for grains, the production of which is to be raised considerably mainly by increasing yields.

Insofar as industrial crops, potatoes, vegetables, and fruits, are concerned, we must naturally utilize both methods extensively - that of expanding acreage under cultivation, and that of sharply increasing yields, in which a tremendous part would be played by application of organic as well as mineral fertilizers. (The necessity of increasing yields is based upon the fact that with low yields we expend at least twice the amount of labor in the mechanical treatment, that is, in pre-planting plowing, and in tending during the growing stage (if this labor is computed not on the hectare basis but per unit of product). Thus, to obtain the same amount of potatoes we cultivate and nest twice, or even three times, the area required in Western Europe, because our yields of potatoes are but half as large. And the more effort is spent on cultivation and care of plants during growing (as in the case of beet, cotton and tobacco crops) the more disadvantageous becomes

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the production of crops with yields as low as those we have been obtaining hitherto, and the higher the cost per labor unit expended in mechanical operations with further application of fertilizers. Hence, an increase in yields is our primary problem, while expansion of acreage under cultivation, in combination with a certain amount of transfer northward for grain crops, constitutes our secondary, reserve means.)

To what extent will the total amount of nutrients removed in the crops increase should our agriculture be developed along such lines? Obviously during the course of this process considerable changes should occur in the ratio of nitrogen removal on the one hand, and those of phosphorus and potassium on the other, since removal of phosphorus and potassium would increase as a result of higher yields and also through expansion of the area under cultivation. Higher percentage of area cropped to clover, alfalfa and other legumes, would further raise removal of phosphorus and potassium, since these plants draw from the soil more ash-producing elements than the grain crops. As to nitrogen, the main factor inducing increased removal is the increased yield of grain and industrial crops, but, if expansion of total plowland area is to be utilized mostly for an increase of acreage under nitrogen fixing crops, this should not cause increased nitrogen removal from the soil, which takes place only by increasing yields.

On the basis of the figure of 4.9 million tons of nitrogen corresponding to the total nitrogen removal by crops, as produced in 1937, and assuming a proportionally greater removal of nitrogen or increase of average grain crop yields up to 16 centners per hectare, the total nitrogen removal should amount to 7.84 million tons per annum. More detailed computations, made at the VIUAA by Scientific Associate M. Kurasheva, resulted in a somewhat higher value amounting to 8.2 million tons of nitrogen. These computations presupposed an increase of acreage under grain crops to 115 million hectares and an average yield of 16 centners per hectare; that under sugar beet to 1.7 million hectares and a yield of 270 centners per hectare; the acreage under potatoes to 10.7 million hectares and a yield of 150 centners per hectare. Yield levels of other crops were assumed as follows: cotton, 22 centners of cotton wool per hectare; flax, 5-6 centners of fiber per hectare; sunflower seeds, 15 centners per hectare; tobacco, 14 centners per hectare; kok-sahgyz, 100 centners per hectare, and so forth.

Thus we find that in order to raise the output of agricultural production to the extent required to meet the problem of catching up with and outstripping the leading capitalistic countries with respect to per capita production, we must ensure the possibility of a total, annual nitrogen removal in the crops of the order of about 8.2 million tons, that is, more than 3 million tons above that of 1937. Naturally this problem could be solved satisfactorily only under conditions of a maximum utilization of all available resources that contribute to an increase on the intake side of the nitrogen balance, since no single item of this intake would ensure compensation of an increase in nitrogen depletion of such magnitude.

Let us consider now those means that we must resort to in solving this grandiose problem.

First of all, consider synthetic nitrogen. This item in the nitrogen balance is most closely connected with the general level of the country's technological might, with its industrialization, and also with its military potential. Application of chemistry to agriculture, as well as mechanization of the latter, are tasks closely connected with problems of national defense: tractors and tanks, ammonium nitrate and ammonal, nitrates and nitroglycerin, all of them are based upon identical industries. Only that country which in time of peace is capable of creating a number of such branches of industry based on economic considerations can be always ready for defense.

In this respect there is a complete dissimilarity between Russia of bygone days, which entered the War of 1914, completely unprepared, and the present position of the Soviet Union. It is only due to Stalin's Five-Year plans that a foundation has been created for the application of chemistry to our agriculture.

In order to assess the achievements of Stalin's Five-Year plans in the field of agricultural development in the USSR, it is necessary to consider, if only in brief, the prerevolutionary past of our country.

Although the old Russia was referred to in Europe as an agricultural country, it was in fact a country having a very poor agriculture, and a partial justification in support of such a designation, is to be found only in the fact that industrially things were even worse; industry was almost non-existent, and hence such a country had to be called an agricultural one. Bygone Russia had very low yields of crops, 7 centners per hectare, which correspond to Germany's level in the 18th century, and to even more remote periods for Belgium and Holland. In addition, due to small acreage under cultivation and excessive rural population, cultivated land amounted only to 0.9 hectare per rural inhabitant (as compared with 3 hectares in Denmark and 5 hectares in the United States); consequently the total grain production was low. As we have seen, it reached only 4 centners of grain per capita for the period of 1908-1913, while in Germany it was 4.6 centners, in Denmark 7.0, in the United States 10.3, and in Canada 19 centners per capita for grain of all kinds.

This was, moreover, combined with a great instability of crop yields, as a result of the low percentage of cultivated land in the forest belt, having a more settled climate, and extensive cultivation in the steppe zone, where the climatic conditions undergo extensive fluctuations and result periodically in famines during drought years. But as a semi-colonial country, dependent on Western Europe, with no industry of its own, Russia had to export grain, and this was possible, as indicated above, only because of the involuntary vegetarianism of the Russian peasant. It can be easily calculated that if the peasant of those days were to think of increasing his meat consumption to the extent of providing even a pound of pork for each member of his family once a week, the 125 million peasants would require about 12 million tons of grain as hog feed, which in turn would absorb and exceed the total pre-revolutionary export. This the peasant could not do; hence

Russian rye, barley, and bran fed the hogs in Denmark and Germany, but not in Russia.

Without discussing the period of chaos, resulting from the First World War and the subsequent Civil War and Intervention, or the reconstruction period that followed, we shall pass to the period of rehabilitation and industrialization of the rural economy.

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In 1927, Comrade Stalin, at the 15th Party Congress, described the hopeless position of small peasant farming, and asked "What is to be done?" He then indicated that the solution resided in "passing to collective farming of land, based on new, superior technology .... with application of scientific methods of intensive agriculture." (Symposium "Lenin and Stalin" Partizdat, 1936, Volume III, Page 235.)

Reverting repeatedly to this problem, he expressly stressed the necessity of intensifying the development of the metallurgical and chemical industries, and said in 1929, "every effort must be made, to provide agricultural machinery, tractors, fertilizers and so forth..." (Ibid, 357).

Even prior to this there were increased efforts on the part of geologists to discover resources not only of coal and metals but also of raw materials for the production of fertilizers. This led to two discoveries of exceptional importance, namely: in 1925, there were located potassium salt deposits at Solikarnsk, the investigation of which in subsequent years showed to be unequaled in size anywhere in the world; in 1926 there were discovered apatite deposits in the Khibinsk Mountains of Kola Peninsula, which development during later years has shown that these also were deposits of exceptional size. Coal resources of much larger scale than those previously known were also discovered. It was found that in the Kuznetsk Basin alone, the coal deposits equaled the combined deposits of Germany, England and France. Water power resources were found to be just as large; those of the Angara-Baykal system alone

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are capable of yielding 20 times as much power as the Dneproges.

Thus, there were made available supplies of raw materials and power necessary for the creation of a phosphate, potassium and nitrogen industry. The First Five-Year Plan (1928-1932) was devoted to more intensive mining and technological prospecting; this was followed by the sinking of mine shafts under the most difficult conditions at Solikarnsk, then the establishment of mines and outfitting of industrial installations. Beginning with the second Stalin Five-Year Plan, there was initiated intensive production of fertilizers, which had increased with each subsequent year.

It was in 1933 that Comrade Stalin made the well-known statement "We had no serious modern chemical industry. We have it now". (Symposium "Lenin and Stalin", Volume III, Page 547).

The rate of increase in fertilizer production during the second Five-Year Plan is shown by the following figures (in thousand tons):

	Nitrogen Fertilizers (20.5 per cent)	Potassium Salts (41 per cent) K_2O	Superphosphates (18 per cent)	Phosphate Fertilizer *	Total
1932 (I)	22.2	27.0	477.6	396.0	922.8
1937 (II)	659.0	407.6	1454.1	634.2	3154.9
Ratio II: I	29.7	15.1	3.05	1.6	3.4

* This refers to that portion of phosphate fertilizers which is utilized directly in fertilizing acidic soils (in addition to phosphate and apatite used in the production of superphosphate).

Taking into account that superphosphates produced in the USSR contain a higher percentage of P_2O_5 than those produced in other countries, and reducing the data to a common denominator, we find that with respect to superphosphate production (1897 thousand tons in 1938), the USSR has attained first place in Europe and second in the world (the United States leads on a world-wide basis), and, in total fertilizer production, has passed from the hindermost position, which it occupied prior to Stalin's Five-Year Plans, to third in Europe, and fourth in the world (in million tons):

Germany	US	France	USSR	Italy	England
7.66	4.78	4.35	3.86	2.05	2.00

Even during the second Five- Year Plan, the utilization of mineral fertilizers had a very pronounced effect on yield increases of those crops which were supplied with them in sufficient quantities. Thus the yields of cotton wool obtained with irrigation methods in Uzbekistan, are illustrated by the following juxtaposition of data showing yield increases resulting from increased applications of fertilizer (mostly nitrogenous and phosphate fertilizers, as only small amounts of potassium salts were used).

Year	1933	1934	1935	1936	1937	1938	1939
Quantity of Mineral Fertilizers Used (in centners per hectare)	0.15	1.66	2.70	5.10	5.64	5.32	5.66
Average Yield of Cotton Wool (in centners per hectare)	8.9	7.9	11.6	16.2	16.1	16.8	17.0

Thus, we have for the entire Republic a two-fold increase in yields for the five-year period (1934-1939), while at individual collective farms yields of 35 centners per hectare were obtained which constitutes a five-fold increase, not to mention much higher yields attained by some Stakhanovites.

An analogous situation is found in Georgia, in the tea crop production, the yield of which has increased more than twice as a result of applying mineral fertilizers, nitrogen fertilizers being the most effective (average over a three-year period):

	1932-1934	1935-1937	1938 - 1940
Fertilizers Delivered (Thousands tons)	1.3	28	51
Tea-Leaf Harvest (kilograms per hectare)	891	1681	2252

In addition to cotton and tea, increased yields were obtained in the case of sugar beet and flax (for fiber), although not to the same extent, because less mineral fertilizer per hectare, is used in these instances.

Clover is of greater importance in crop rotation and manure is of much greater significance than in cotton crop rotation.

An interesting picture is displayed by the progress of the yield in the production of sugar beet in Kirgiziya, where utilization of mineral fertilizers is more effective, than in the Ukraine, since irrigation obviates the limiting factor of precipitation rate. Average yields in Kantskiy Rayon (the leading one in Kirgiziya) are as follows:

Year	1934	1936	1938	1940
Amount of Fertilizer (centner/hectare)	3.5	8.2	11.9	14.5
Yield of Roots (centner/hectare)	166	345	349	471

To evaluate the significance attained by mineral fertilizers at the beginning of the Third Five-Year Plan, the following computation, made by professor P. A. Baranov, may be used. If we consider only the total increase in the yield of four crops (cotton, sugar, tea and flax fiber) attained in 1939 by the use of mineral fertilizers, then, in terms of the market price, this increase in the above-listed items amounted to 4 billion rubles, while fertilizer costs aggregated 600 million rubles.

According to the plan for 1945, total production of the fertilizer industry is to be doubled (in comparison with that of 1937), hence the value of yield increases for all the crops should attain 9 billion rubles.

Inasmuch as the areas wherein industrial crops are raised are far from being fully provided with the necessary quantities of fertilizers, a substantial increase in value of industrial crops production as a result of fertilizer utilization is assured for a number of five-year periods.

With respect to the application of fertilizers to industrial crops, we have in a number of instances caught up with and outstripped Western European countries, in the amount of fertilizer applied to each hectare of land. This applies to the irrigated areas of Central Asia and the humid subtropical regions, where we are limited in available space, and high yields are of paramount significance.

In Uzbekistan, where irrigation is used, with cotton growing predominating the amount of fertilizer per hectare of cotton (in prewar years) was 106 kilograms of NPK, which is considerably higher than the average rate in Germany, and which approximates the average figure for Holland (109 kilograms), the latter occupying the first place in the amount of fertilizer applied per hectare for the total sown area. Georgian tea plantations receive about one ton of fertilizer per hectare (196 kilograms of NPK). This exceeds the average figure for Holland. Of course, in the case of Georgia, we are considering here only the area occupied by the tea plants, the cultivation of which does not involve crop rotation, while the corresponding figure for Holland represents the average value computed on the basis of total cultivated area. With an analogous reservation, it can be pointed out that Ukrainian sugar beet plantations were supplied with 8 centners of fertilizer per hectare (or 150 kilograms of $N + P_2O_5 + K_2O$), which is more than one and a half times the overall German average.

Thus, in the case of industrial crops we utilize an intensive cultivation, which has caught up with and is even outstripping Belgium and Holland in the amount of mineral fertilizer used per hectare. But this does not mean that we will

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have to use the same method in the case of grain crops, wherein we are not limited in space. Here an entirely different approval must be resorted to.

That which is suitable for selected crops does not at all apply to all crops, to the entire cultivated area of the USSR. Here we do not strive at all for attaining the Dutch standard in the amount of mineral fertilizer used per hectare. However, we must excel all Western countries in the amount of grain and other agricultural products, produced per capita by taking advantage of that factor which is lacking in Holland and Belgium, i.e. the extensiveness of our land area. Indeed we cannot compare the USSR with a country like Holland, which is situated entirely within a single climatic and soil-type zone, with identical economic conditions throughout, and is densely populated and deprived of any possibility of increasing its tilled areas, with the exception of very costly recovery of small parcels of land from the sea. The Soviet Union, on the other hand, consists of most diversified zones, differing not only in climatic conditions and soil, but also in population density, and above all amply supplied with still unutilized arable land. Hence we can not only increase the yields of our crops, without however aiming at overtaking Holland in yields per hectare, but also raise the total yield of grain by expanding the acreage under cultivation as a whole, and that cropped to clover in particular, and thereby increasing grain yields without resorting to extensive use of mineral fertilizers by the beneficial effects of clover upon the soil, either directly or by means of manure derived from the clover.

(What has been said above applies to the general scheme of allocating mineral fertilizers to industrial and grain crops. But the diversity of natural and economic conditions encountered in our country precludes, of course, any hard-and-fast rules. More specifically, even at present it is timely to raise the question relative to the possibility of a gradual change to the next phase in the intensive application of chemistry to our agriculture, namely: the use of mineral fertilizers not only for the production of industrial crops, but to a certain extent, for the areas cropped to grains and other food (and feed) crops. In this connection it is important to select properly those conditions, under which such a method would result in maximum technological and economic attainments. To begin with, there can be planned creation of large centers of intense application of chemical means in agriculture within oblast's and rayons including industrial centers, and within zones adjoining main transportation lines. Sharp yield increases of all crops by means of chemicals attained by such regions (under favorable soil and climate conditions) may be an important factor in facilitating the solution of food supply problems pertaining to such industrial centers, and at the same time alleviating transportation difficulties.)

ON PROSPECTS FOR THE MINERAL NITROGEN FERTILIZERS PRODUCTION AND UTILIZATION

What means are available to us for further increasing the supply rate of mineral nitrogen fertilizers to agriculture? It must be pointed out, that measures taken during the war to en-

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sure the needs of military industries, (transfer of a portion of the nitrogen industry eastward, putting into operation new installations), will have a benficial effect upon the total output of nitrogen fertilizers, being allocated to agriculture.

It must be assumed that reconstruction of chemical industry establishments within the territory of areas which were devastated during the German occupation, will not involve decreased output at those plants which were set up in the East during the war, since Gorlovka and Stalinogorsk are to be supplied with new equipment. But in addition construction at new sites will also be needed, taking into consideration the most efficacious distribution of industrial installations of this type, and solving the problem of production trends with respect to selection of basic synthetic methods and choice of products to be manufactured.

The distribution of nitrogen fertilizer production centers, and the establishment of their putput capacity, do not involve problems of raw material supply,- air always contains the same amount of nitrogen, irrespective of location; decisions are based on availability of power sources - black and white coal. (Wind power as yet is not utilized for this purpose).

With respect to coal resources the Soviet Union is in a very favorable situation, a fact ascertained only after the Revolution. In 1913 our resources were estimated at 220 billion tons, whereas now they are stated to be 1654 billion tons, that is 2.5 times the total coal resources of West-European countries (but the United States has 3795 billion tons).

In the European portion of the Union the largest coal resources are located in the South in the Donbas which has about 90 billion tons, and in the North, in the basin of the Pechora River, whereto a main railroad line was built during the War. But best provided with coal is Siberia (including the area from the Urals to the Pacific Ocean), it contains about 90 per cent of our total coal resources; the Kuznetsk basin alone contains deposits amounting to approximately 450 billion tons, which is 5 times as much as in the Donbas, and is almost equal to the total resources of Germany, England and France (480 billion tons). It is known that in addition to supplying the needs of local industry, such as the nitrogen plant at Kemerova, and a number of other installations. The Kuznetsk coal is used to supply the largest metallurgical plant of the South Urals (Magnitogorsk), while iron ore from the Magnitnaya Mountain is carried by trains on their return trip to Kuzbas Dual-Purpose Combine. Since coke is produced from Kuznetsk coal partly at the site of mining, and in part at Magnitogorsk both locations afford extensive possibilities for establishment of Synthetic ammonia plants.

With all its huge capacity the Kuznetsk Basin is not the largest coal deposit site in Siberia, since even greater amounts are in prospect within the Tunguss Basin, occupying a tremendous area (about 1 million square kilometers) bound by the Yenise and Lena, the Krasnoyarsk Railway and the Artic Ocean.

But utilization of these coal resources is a task of the future; the same applies to coal of Taymÿr, that within the Lena

Basin, in Yakutiya (not less than 200 billion tons) and the northeastern part of the Arctic region. At present there are in production mines drawing upon the deposits of the more southern portion of Siberia, such as those at Kansk, Chulymo-Yenisey, and Minusinsk basins, the Irkutsk Basin having a 73 billion ton deposit of coal. (The Cheremkhovo deposit is being mined). Also of great importance are the Bureya coal fields in the Priamur'ye, the Suchansk region supplying coal to Primor'ye; there is coal also on Sakhalin and in Kamchatka. In central Asia, Kazakhstan has large deposits such as those of Karaganda, computing 52 billion tons; there is coal, although in lesser amounts, also in Kirgiziya, Uzbekistan and in Turkmeniya.

We have also huge resources of "white coal"; while "Great Volga" is the current project, we still have to put to use the tremendous power resources of Angara, Yenisey and other rivers of Siberia. However, utilization of water power on that scale is beyond the scope of the Fourth Five-Year Plan and in the meantime coal deposits can be used. In this also, as in problems relating to phosphorus and potassium, besides the huge figures giving the total resources, the problem of most advantageous geographical location is of great importance, when though it be for the time being that small portion of the resources available, which is available immediately, direct utilization.

Until recently insufficient determination of distribution and in part also inadequate development of known coal mining areas, have caused such abnormal situations as the shipment of nitrogen fertilizers over distances of 3 - 4 thousand kilometers. The cotton growing areas of central Asia are our main consumers of these fertilizers, since grey desert soils are naturally deficient in nitrogen, and the area of possible cotton cultivation is limited by temperature conditions and still more by the impossibility of raising cotton in Central Asia without irrigation. This creates an oasis-like type of cultivation, precludes allocation of substantial areas to forage crops, resulting in lack of manure and the necessity of using more nitrogen fertilizers than in growing beets or flax. But our nitrogen plants were located far from cotton-growing areas, operating as they were on Kizel, Moscow and Donets coal; and Uzbekistan was then not known to contain any deposit of coal fit for coke production. This led to construction of the Chirchik Combine (near Tashkent) which utilizes water power for electric current production, to manufacture hydrogen by electrolysis of water; nitrogen is obtained by fractional distillation of liquid air. This method is utilized, however, only perforce in countries without coal and water falls, since it requires expenditure of a large amount of power per unit of fixed nitrogen. According to Casale, at least 18 kilowatt-hours are needed to produce 1 kilogram of fixed nitrogen, but in operating on coal by the Haber method the expenditure is only 4 - 4.5 kilowatt-hours.

It is readily apparent, therefore, why Germany, France, and England who have coal, do not use the Casale method, which is utilized only in Italy and Norway, where no coal is mined, and hence these countries are compelled to expend 4 - 5 times more power in the fixation of a unit of nitrogen than those countries which have coal. While it has been contended that there is no reason to have a hydroelectric power, since it is "free", actually however it is always found to be costly because of large expenditures necessitated by capital construction. (The influence of this factor is being felt at Chirchik.)

In the past, expenditure of large amounts of water power was deemed unavoidable in the case of Central Asian nitrogen industry, but as early as 1937 there were indications that the coal situation was undergoing a change in Central Asia. After better communications were established with the remote Yagnob Valley, which had been thereto completely isolated from the rest of the world (within its limits there even survived a distinct dialect, closely related to Persian, which had become extinct in other parts of Tadzhikistan), geologist were able to reach this area and found there a large deposit of good coking coal. Since the distance from there to Tashkent probably does not exceed 300 kilometers; this discovery may change the Chirchik situation. If the Yagnob coal becomes readily available it would be more advantageous to utilize the electric power for industrial needs, and convert the Nitrogen combine to the Haber process.

In addition to Yagnob coal, coal deposits were found in Fergana (Naryn Valley). On final analysis it is more advantageous to transfer the plant to the coal mine, then to ship coal to the plan, since it is much easier to ship the final product (NH_4 NO_3) than to ship coal.(Should the local deposits be found to be insufficient in quantity or consist of low-grade coal, consideration might be given to using karaganda coal, being guided in this by the same principle: "Mohammed is going to the mountain, and not the mountain to Mohammed", that is, the plant is built at Karaganda, and Tashkent is supplied with ammonium nitrate. But here the difficulty comes in with respect to the lack of water at Karaganda. An intermediate solution could then be adopted. Since the plant is built beside such a rich supply of fresh water as is afforded by hake Balkhash (at its western portion, not at the brakish eastern one) the ammonium nitrate will have to be shipped by rail (Second Turksib) about 400 -500 kilometers, and this distance, considering the concentrated nature of the product, does not constitute an obstacle to its conveyance into cotton-growing areas.)

What has happened at Chirchik can happen again also in other instances. For example, of only one of the possible Angara River dams is built, at first a huge surplus of electric power would become available. It would be only natural to apply this surplus for production of fixed nitrogen; but later on as industrial centers develop, this power would be required by other consumers, and then production of synthetic ammonia should be shifted from white coal to black coal. Even so, the temporarily available supplies of hydroelectric power can be more advantageously utilized not for water electrolysis and ammonia synthesis but for production of cyanamide, because this production requires one and a half times less power in the fixation of a unit of nitrogen, than the Casale process, about 11.5 - 12 kilowatt-hours in lieu of 18, which means that the plant output can be increased by 50 per cent. For this reason production of cyanimide in Italy increased not only as such but also in relation to total fixed nitrogen production. Furthermore, cyanamide shared with ammonium sulfate the predominant position on the nitrogen fertilizer market.

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(Utilization of nitrogen fertilizers in Italy increased as follows (in thousand of centners):

	Ca CN_2	$(NH_4)_2So_4$	$Ca(No_3)_2$	$NaNo_3$	Nh_4No_3
1930	762	1046	231	640	158
1934	1396	1312	857	553	284

It is true that in cyanamide production, not all of the 12 kilowatt-hours are supplied as electric power, and for each 10.5 kilowatt hours of the latter it is necessary to provide also 1.5 kilograms of coke. But this amount of coal, it would appear, could be supplied even from Karaganda. Another advantage of the cyanamide process over the ammonia synthesis should be borne in mind. In the former process, nitrogen fixation is conducted at ordinary pressure, while ammonia synthesis requires at least 200 -250 atmospheres. Thus the need of expensive equipment is eliminated, for providing such equipment is one of the limiting factors in the development of the nitrogen industry. In general the combination of nitrogen with carbide proceeds very readily (with evolution of heat), considerable expenditure of power is needed only in the production of carbide which further required the know-how for production of large-size electrodes.

But we have already mastered this production method. In any case carbide production should be developed on a large scale, by us for other reasons as well. It is an important intermediate in the synthesis of rubber from acetylene. This method of producing synthetic rubber from coal and water (its

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hydrogen) would release a huge amount of potatoes which are so badly needed both as food and in the development of animal husbandry (hog feed).

In addition to the simplicity of the moratin process, the cyanamide that is produced may be used directly in prepared fertilizer, whereas ammonia must be combined with sulfuric acid, or one half of it passed through oxidation units in order to obtain ammonium nitrate; and oxidation of ammonia in addition to its cost results in a certain loss of nitrogen.

While in the old cyanamide plants there existed conditions detrimental to the workers' health (inhalation of cyanamide dust), most modern grinding units provide for a complete segregation of air in working areas from air containing cyanamide dust. Another contention, that it is more difficult to produce nitric acid from cyanamide than from ammonia, can be met by providing cyanamide- producing plants not <u>in lieu</u> of ammonia plants but <u>in addition</u> to such plants, any number of which can be provided by using coal (not only in the Donbas and in the Urals, but also at Prokop'yevsk, Kemerova, Cheremkhovo, etc), and manufacture of ammonia using coal requires four times less power than is consumed, for instance, at Chirchik.

Since our agricultural requirements in nitrogen greatly exceed all others, but to the huge expanse of our cultivated areas, we can fulfill to the utmost degree all other needs and still retain a wide margin for further development of the nitrogen industry solely for agricultural requirements, and within this margin make a free selection of those nitrogen fixation methods, in which power is expended more productively than in the electrolysis procedure.

Incidentally it is characteristic, that in the West, cyanimide production is being developed not merely in those areas provided with hydroelectric power, but also where the coal is of such a quality as to render it unsuitable for use in ammonia synthesis. Thus in Germany the largest cynamide plant at Piesteritz utilized electric power supplied by a neighboring plant which utilized most conveniently located brown coal deposits consisting of a large stratum situated near the graund surface, so that mining could be conducted by open-pit excavation with automatic dredging and conveying to the surface, in a manner somewhat analogous to that used in the production of peat (the coal layer being however of much greater thickness). It is characteristic that the cheap electric power thus obtained was used not for any electrolysis of water, but to produce carbide which was then converted to cyanamide. We certainly do not lack extensive brown coal deposits, such as those near Chelyabinsk and in different areas of the Kuzbas.

It must be noted that as soon as short-duration field experiments were replaced by experimental stations where the after-effects were taken into account, it was found that cyanamide is the best nitrogen fertilizer for podsolic soils. Thus at the Luberetsk experimental area of the NIUIF located in a poor fertility region of podsolic sandy loam repeated applications of cyanamide resulted in yields which gradually increased over a period of years, while all ammonium salts used producted not only annually decreasing results but also a negative effect in the absence of liming. (See Table):

Consecutive Yield Alterations on Repeated Appliation of Nitrogen Fertilizers in Per cent of Yield on KP Plots

Yeons	Cyanamide	$NaNO_3$	$Ca(NO_3)_2$	NH_4NO_3	$(NH_4)_2JO_4$	NH_4CI
2	188	156	145	163	149	156
4	182	198	153	109	88	79
6	225	212	192	67	38	30

Thus cyanamide constitutes not only a nitrogenous but also a lime-containing fertilizer, and the lime is added without any extra cost to the nitrogen content. It does not follow, of course, that cyamide should be produced everywhere; it still requires more power than the Haber process. But cyanamide can be produced where there is little good coal and an abundance of brown coal. In other cases ammonium salts should be supplemented by calcium, "liming if not the soil then the fertilizer." This can be done by adding ground limestone to the NH_4No_3, for podsols in proportions used in England (40 Per cent); and for long-distance shipments to Central Asia where the soil is rich in calcium a different method of lime addition must be applied (a minimum amount of $CaCo_3$ necessary to improve the physical characteristics of ammonium nitrate). The most interesting component of ammonium nitrate containing mixture is dicalcium phosphate dihydrate; this was established in France. But at present our production of dicalcium phosphate dihydrate is as yet too little developed, that it is desirable to test admixtures of ammoniun nitrate and phosphate powder, using one ration to improve the physical characteristics and another to promote dissolution of the phosphate rock powder on combined application (experiments conducted at NIU have long since established the beneficial effect of a preliminary admixture of phosphate rock powder to ammoniun salts, which promotes their mutual commingling in the soil.

In England they add calcium carbonate to improve the physical characteristics of ammoniun nitrate. This, however, does not exclude the possibility of some loss of ammonia. In this respect a better component is clay, by the addition of which granulated ammonium nitrate is produced. The present author saw such granulated ammonium nitrate when he visited the Ude plant at Dortmund in 1932. The mixture contained 30 per cent nitrogen, but it is quite possible that the proportion of clay (properly selected, of course, not just any clay) could be further decreased. In any event in the West, ammonium nitrate is considered to be not a finished fertilizer product but rather as a good material for its manufacture (by mixing with dicalcium phosphate dihydrate or ammonium phosphate and Potassium salts).

Taking into consideration what has been said up to now concerning the possibility of planned application of mineral fertilizers to grains and industrial crops in relationto the desirable allocation of synthetic nitrogen to agriculture, we must in the first place consider as fundamental the problem of meeting the requirements of industrial crops, vegetables and fruit, for such fertilizers, and to a considerably lesser degree those of grain crops. (The latter may be considered also of primary importance under conditions of irrigation farming.) The nitrogen supply for grains must be provided, not only by the manure, but also by expanding the acreage under nitrogen collecting crops, because only thus can the tremendous nitrogen requirements be satisfied which arise on increasing the average yields of grain to 15 - 16 centners per hectare.

Among the first claimants to a heavy application of mineral fertilizers we will include, together with industrial crops, potatoes and root plants, because of the fact that these crops pay for the fertilizer cost about three times, on the basis of dry products' increase.

Determination of the amount of mineral fertilizers needed for national agriculture is, of course, a fairly complex problem. The potential intake capacity of our agriculture for mineral fertilizers utilization is indeed a huge one. Hence requirements that we may make to our nitrogen industry must be determined, on the one hand, by the potential development rate of this industry, and, on the other, by the demand for synthetic nitrogen for raising yields of agricultural crops, and in so doing we must always bear in mind the possibility of utilizing other sources of supplying credit items of the nitrogen balance, the increase of which can be resorted to compensate shortages of synthetic nitrogen.

We have already indicated that if we were to utilize, for all crops, mineral fertilizers on the scale they are used in Holland, Belgium and Germany, we should arrive at figures that are absurd. Our acreage under cultivation had reached 150 million hectares before the War, and if mineral fertilizers were to be used thereon on a scale such as that on which they are used in Holland, that is, two-thirds of a ton per hectare, we would need 100 million tons of fertilizer, which is 30 times more than we produce at present, and twice the amount manufactured by the fertilizer industry of the entire world. Furthermore, Holland utilizes six times as much manure as we do, but to do so, she has one half of the acreage under cultivation devoted to fodder plants and in addition has a huge area of good pasture land equal in size to the acreage under cultivation.

We cannot burden our chemical industry with excessive assignments; the acreage under cultivation cannot be utilized in the manner it is done in Holland, because there animal husbandry has superseded grain crops, and a large amount of manure is obtained for a small area cropped to grains, so that they have long since switched to imported grain. But we have no need to attempt production of 100 million tons of fertilizer and to imitate Holland in overemphasizing animal husbandry, because attainment of average yields obtained in Holland (30 centners per hectare) is not our aim insofar as the entire territory of the Union is concerned. With 110 million hectares devoted to grain (including the Western republics), we would have a total harvest of 330 million tons, or 20 billion poods, an amount we have no need for at present, since one half of it is all that is required, even on taking into account export possibilities.

Generally speaking it is an error to take Holland as an example which is crowded against the Sea, or land-poor Belgium, where all that can be tilled is being tilled. These small countries are homogeneous in natural and economic conditions. In our Union, occupying one sixth of the world's dry land, consisting of a number of republics and Krays dissimilar in prevailing conditions, the problem of raising crop yields must be solved differently in different instances, and the statistical average for the entire Union, in our case is composed (and should be composed) of much more diversified components than in the above-named, small, and more homogeneous countries.

Hence, not only at present, but in the future as well, on using mineral fertilizers, as a matter of principle, a definite bid must be made for industrial crops, as more adequately compensating for fertilizer cost, and also because on substantial saturation in crop rotation, as for example by cotton (which is made necessary by limitation of cultivation areas by climatic conditions) it is impossible to develop cultivation of nitrogen fixing crops (See below, on conditions inducing nitrogen starvation in cotton growing of central Asia.) and to increase manure production, as this can be done, for example, in Moscow or Smolensk oblast's. Sometimes it is even necessary to resort to single-crop cultivation (tea plantations in Georgia). In other instances substantial limitation of crop rotation by the main industrial crop is caused by the necessity of maintaining within the vicinity of a processing plant, fields yielding a bulky raw material (beets, flax, potatoes), or to maintain the growing of vegetables close to population centers. But limitation of crop rotation by these crops which require much fertilizer, also restricts the area cropped to manure producing plants (fodder) and thus makes it necessary to utilize mineral fertilizers. Consequently, mineral fertilizer requirements of industrial crops must be met in first priority. However, on our scale, the total area devoted to these more valuable crops is still very large. Industrial crops, within the strict meaning of the term, occupy 11 million hectares, vegetables (including field potatoes) 2.5 million hectares, orchards and vineyards 2 million hectares. The total adds up to 22.5 million hectares.

The assessing of mineral fertilizer requirements of these crops can be effected in various degrees of detail. If we assume 50 - 60 kilograms of nitrogen per hectare for the entire area as an average requirement we obtain a figure of the order of 1.2 - 1.3 million tons of nitrogen. Naturally, not all industrial crops require the same amount of mineral fertilizer. The dosage as well as the percentage of fertilized area can obviously differ widely, due either to peculiarities of the crops, such as flax and cotton, or dissimilar soil conditions in cultivation. Therefore within the limits of total average requirement there is room for substantial possible adjustments to attain maximum utilization of fertilizer.

We must point out that the relationship between the amount of fertilizer and magnitude of yield increase is not at all of such a simple nature, as is sometimes represented. For example, an addition of small amounts of nitrogen fertilizers, especially on poor soils, frequently results in increased effectiveness of fertilizer correlated to increases in the dosage (contrary

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to the well-known curve of Mitscherlich) In the old experiments of Wagner on application of different doses of ammonium sulfate to winter rye applied in the spring: the following yield increases were observed.

Amount of Fertilizer (centner/hectare)	1.6	2.0	2.4
Grain Yield Increase (centners/hectare)	4.34	6.87	9.33

On computing average yield increase per centner of fertilizer, we have:

Amount of Fertilizer (centners/hectare)	1.6	2.0	2.4
Grain yield Increase (per centner of fertilizer)	2.71	3.44	3.89

Consequently in these experiments the first centner of fertilizer is compensated for less well than the succeeding one. Wagner not only determined this fact but gave it an explanation that came to be well-known at the time.

He ascribed the following reasons for the inadequate effect of small amounts of nitrogen in poor soils:

(1) Nitrogen-starved plants have an abnormal composition. They contain less nitrogen. On introduction of a limited amount of nitrogen a portion thereof is consumed to remedy the abnormal composition, and only the remaining part is utilized to increase the yield, hence the inadequate compensation when using small amounts.

(2) In starved plants, the ration in development of the organs does not correspond to a normal; the percentage of root is higher in them than usual, and the percentage of parts above the ground is lower. The first portions of nitrogen are used up to correct this ratio (intensified development of vegetative organs - stems and leaves), and only the succeeding amounts manifest their action primarily in grain formation. Thus in oats, without any fertilizer, the parts above the ground constitute 42 per cent of the total mass of the plant, and the roots 58 per cent. Following the first dose of nitrogen this relationship was 65 per cent to 35 per cent, and on a further addition of nitrogen it became 81 to 19 percent. In other words the plant has a certain necessary outlay, so to speak, and only after these have been met, is there a possibility for a productive utilization of subsequent doses of nitrogen.

On this basis Wagner reached the following conclusion: On poor soils producing yields of 10- 12 centners of grain, but not inferior in physical properties, fertilizer must be applied in amounts of not less than 2.5 - 3 centners per hectare (calculated as salpeter). If there is a shortage of fertilizer, it is better to apply it at this rate over a smaller area, than to provide the entire area with a smaller amount. If on the other hand the soil is prepared and yields on a potassium-phosphorus base 20 - 25 centners of grain, a lesser amount of nitrogen (20 - 30 kilograms) can be used with a good chance of attaining the proper yield increase per each centner of fertilizer.

The first case, where small doses should not be used was met with in prerevolutionary experiments, when poor land owned by peasants was treated with 1 centner of salpeter per hectare and no adequate effect was attained.

In 1926, however, when NIU conducted large-scale experiments using amounts of fertilizer like those utilized in Western practice, that is, 45 kilograms of nitrogen per hectare, it was found that in our country the effect of fertilizer was no worse than in other lands. This feat is of substantial practical importance, since it indicates that with insufficient fertilizer, its application should not be effected on the basis of covering the largest possible area, but that it should be used, even if not over the entire area, in amounts to ensure the highest return per unit of fertilizer. In this we will, of course, encounter a wide variety of conditions (farming with or without irrigation, type of crop, etc.), but it is still important to keep in mind the basic premise that <u>too small amounts of fertilizer frequently cannot produce the proper result.</u>

On the other hand it should be remembered that increase of fertilizer dosage beyond a certain level (<u>this level will vary depending on specific conditions</u>), can in its turn lead to a lesser return of fertilizer costs by yield increases. If we should increase the dosage beyond that quantity of nitrogen called forth by the given conditions, would use less by increasing the denominator when the numerator remains constant; that is, we are decreasing the compensation factor, just as in the case of too low a dosage the compensation factor cannot attain its optimum value. Such a relationship was observed by Wagner on comparing results of collective experiments conducted by the German Agricultural Society, as well as of results obtained under different conditions. On the average, the following correlation was observed between nitrogen amounts and yields of winter rye (on the PK base):

	Amount of Ammonium Sulfate per Hectare						
	1	2	3	4	5	6	7
Grain Yield Increase (centners/hectare)	2.5	7	13	16	19	20	20
Average Return in Grain for 1 Centner of Fertilizer	2.5	3.5	4.3	4.0	3.8	3.3	2.9
Return on the Last Centner.	2.5	4.5	6.0	3.0	3.0	1.0	0

We thus ascertain that there is a certain optimum dosage for a given crop level, at which the highest average return in grain is obtained for each centner of fertilizer. The optimum varies, of course, depending on the base upon which the experiment is conducted.

Phenomena analogous to those just described are observed also in experiments conducted with industrial crops. We can cite an example derived from data of the Kaunchinsk Station in Central Asia relative to increasing dosage of nitrogen applied to cotton (30 - 60 - 90 kilograms nitrogen, etc., up to 300 kilograms of nitrogen per hectare) under conditions of irrigation culture. Optimum return in yield increase per unit of fertilizer was found to be in this instance to come with higher dosages. Of interest also are the differences observed on using $(NH_4)_2SO_4$ in place of NH_4NO_3. Let us consider both experiments.

Here are the results of the NH_4NO_3 experiment, taking into account effects obtained during the first year and the after-effect taking place during the second year following the application of fertilizer.

Nitrogen Added (kilograms/hectare)	30	90	120	180	300
Cotton Wool Yield Increase (centners/hectare)	3.5	10.3	19.8	22.9	24.5
Cotton Wool Obtained (in Kilograms) per Kilogram of Nitrogen	11.6	11.4	16.5	12.7	8.2

Within a certain interval, the increase of cotton wool yield per each kilogram of added nitrogen, increases with higher dosage.

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Return in yield on the nitrogen rose gradually on increasing the dosage from 30 to 120 kilograms. On further increase of dosage, yield increase rose more slowly, but a yield drop as a result of excess fertilizer was not observed in this instance.

In the experiment with $(NH_4)_2SO_4$ we have at first the same correlation, but the highest yield increase in this case was only 17.9 centners (as compared with 24.5 centners in the case of NH_4NO_3). Furthermore, the right-hand portion of the curve shows a drop as a result of excess fertilizer.

Nitrogen Added (kilograms/hectare)	30	90	120	180	240	300
Cotton Wool Yield Increase	2.3	6.7	12.9	15.5	17.9	15.0

If we plot the curve of yield increase for increasing doses of fertilizer, and also show the curve of return variation for each additional unit of fertilizer applied (in this instance with each 30 kilograms of nitrogen), as well as the average return for an increasing number of such units, we have in the case of an experiment using NH_4NO_3, the following graph:

Figure 34. Effect of Increasing Amounts of NH_4NO_3 on yield of Cotton Wool. (See original text)

I - increase of cotton wool; II return in yield for each additional unit of fertilizer; III average return in yield per fertilizer unit.

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The curve of yield increase shows in its initial portion a deflection not to the left but to the right (In contradiction to Mitscherlich's curve) from an ascending straight line. The curve returns on each successive unit of fertilizer (30 kilograms of nitrogen) shows a definite optimum at 120 kilograms. On either side of this optimum the return decreases. With increasing dosage this curve tends toward the abscissa axis, but does not intersect the latter. Average return per unit of fertilizer is also at its peak at 120 kilograms, but, for readily apparent reasons, declines more gradually on either side of the optimum.

Figure 35 shows the results of the experiment with $(NH_4)_2SO_4$.

Here we note the following peculiarities. The left-hand position of the yield-increase curve, shows also a gradual increase with augmented dosage. When the dosage is increased from 240 to 300 kilograms, a pronounced drop is shown, as a result of fertilizer excess. The curve of return per each additional unit of fertilizer shows an optimum at 120 kilograms, but in contradistinction to the NH_4NO_3 experiment, it crosses at higher dosage the axis of obscissa and acquires negative values.

In these experiments there is to be observed the same progress of change as that noted in Wagner's experiments with cereal grains. But, whereas Wagner's experiments which were conducted in the absence of irrigation, the optimum was reached at 60 kilograms of nitrogen, in the experiment with the irrigated cotton crop the optimum was attained at twice as high a disage.

Figure 35. Effect of Increasing Doses of $(NH_4)_2SO_4$ on Yield of Cotton Wool.

I – increase of cotton wool yield; II return in yield for each additional unit of fertilizer; III average return in yield per unit of fertilizer.

Thus the size of an optimum fertilizer dosage is a relative one. In addition to such factors as irrigation, the optimum can be shifted toward higher values by changing the method of applying the fertilizer as well as the agrotechnological level in general, Selection of suitable kinds of fertilizer, and so forth.

Instances of record-breaking crop yields obtained by leaders of socialist agriculture may be used as examples illustrating this relationship, where on increasing the general level of agricultural technology, it was found possible to apply successfully much higher amounts of fertilizer than those usually applied on a large scale.

In these instances, however, one should not be overpreoccupied with the use of inordinately high doses, since a certain optimum is present here also, although it is found at a higher level.

At the same time it must be pointed out that concurrently with efforts directed to an improvement of the overall system of agricultural technological methods, it is necessary to utilize the combined application of mineral and organic fertilizers in order to attain high yields. Under these conditions it is possible to attain very satisfactory results, as stated herein before, even by the use of relatively small amounts of mineral fertilizer. In any case the primary aim of attaining a maximum return on each unit of mineral fertilizer used must be adhered to, while we should refrain from use of too small amounts (to cover large areas), as well as preoccupation with excessively liberal application of fertilizers.

Fertilizers must be used extensively, in amounts much higher than those corresponding to a statistical average standard, in the case of a considerable portion of valuable industrial crops, which yield high returns on fertilizing expenditures, with variations depending on the conditions of cultivation (climate, soil, and technology, irrigation, care etc.) to ensure adequate provision of foodstuffs.

Among these are for example, tea and cotton plantations, which received in our country (in 1937 -1941) an amount of fertilizer exceeding, on the per hectare basis, the average amount of fertilizer used in Holland, which leads among Western European countries in the utilization of chemicals in agriculture. In the case of beets and flax, the use of mineral fertilizers was practiced on a considerably lower level, and for these crops the immediate problem would be attainment of the intense use of chemicals approximating that average level maintained before the war in West-European countries. Sunflowers, on the other hand, grown as it is on the rich chernozem areas

areas of Kuban' do not as yet require large quantities of mineral fertilizers.

There were made, in this country, attempts to compute on such a more particularized basis mineral fertilizer requirements of different industrial crops, with allocations of a portion of nitrogen to the grain crops as well. (M. L. Kurasheva (VIUAA); see also V. P. Kochetkov, Khimizatsiya Sotsialisticheskoyo Zemledeliya - the use of Chemicals in Socialist Agriculture.. Nov 7, 1937.) Without considering in detail these computations, we can merely point out that on maintaining the general principle of first priority allocations to meet the needs of industrial crops, the minimum requirements of mineral nitrogen fertilizers approximate in this instance the figure of 1.3 million tons of nitrogen. If this value is adopted on a basis, in the establishment of a proposed nitrogen balance for the USSR, it is readily apparent, that in order to increase crop yields within a major portion of our territory, there must be utilized on a most extensive scale, methods of solving the nitrogen problem, other than that of using mineral fertilizers.

ON INCREASING INTAKE OF BIOLOGICAL NITROGEN. PROSPECTIVE NITROGEN BALANCE IN USSR AGRICULTURE

In order to express more forcibly the magnitude of acreage under cultivation within the USSR it is sufficient to say that even prior to changes which occurred in 1940, our acreage under cultivation (140 million hectares) was equal to that of all other European countries put together, including Turkey. Alteration of the western border has raised it to 150 million hectares, arable land including fallow computing 175 million hectares, or 205 million hectares counting unused land.

We recall that the total removal of nitrogen by crops approximates in our country 5 million tons (according to 1937 data), and with the proposed increase of average grain yields to 16 centners per hectare it should increase to about 8 million tons, which is more than three times the annual production of nitrogen industries of the entire world.

Obviously with a cultivated area of such size and the huge nitrogen removal that goes with it, it is out of the question to solve the entire nitrogen problem as a whole, with the aid of the chemical industry. Basically it must be solved by growing nitrogen gathering crops, since our land area allows increasing acreage cropped to them in a proportion commensurate with grain crops. This source of nitrogen may be considered as involving no extra expense, since costs of growing clover (and other forage crops) are defrayed by livestock raising.

But in order to utilize fully the biological nitrogen of clover and of other feed legumes it is necessary, concurrently with extensively expanding the acreage of such crops, to ensure a substantially more complete and efficacious utilization of manure. In the absence of this condition it is impossible to equate adequately the balance of nitrogen and attain the necessary rate of yield increase. Indeed, a considerable portion of the nitrogen fixed by legumes is present in their overground parts, and this nitrogen, on final analysis (insofar as feed legumes are concerned) is found in the manure.

Consequently only under conditions of careful management of manure nitrogen, can a basic improvement of nitrogen balance be effected through the concurrent expansion of acreage cropped to nitrogen fixing plants.

Insufficient manure utilization is the main cause of our most unfavorable intake and expenditure balance not only in the case of nitrogen but of other plant nutrients as well. In the last decade, unfortunately, a decrease rather than an increase of manure utilization has taken place. At the beginning of the First Five-Year Plan the quantity of manure utilized annually, was estimated at 300 million tons, during the Second Five-Year Plan this figure shrank to 200 million tons, and in 1940 according to data of NKZ USSR, only 125 million tons were used, that is, less than one ton per hectare of the acreage under cultivation.

It is true that over this period there took place a certain expansion of the area cropped to forage grasses, with a corresponding increase of nitrogen amount in clover root residues in the soil, but the total nitrogen deficit still reached almost 74 percent. (See Table).

Balance for 1940

Of That Removed by Crops (100 percent), There Was Returned Through:	Nitrogen in percent	Phosphorous in percent	Potassium in percent
Manure	14.8	16.1	19.1
Mineral Fertilizers	3.2	15.6	4.8
Legume Roots	8.2	-	-
Total	26.2	31.7	23.9
Deficit	73.8	68.3	76.1

West-European practice shows that to ensure a systematic yield increase it is necessary to return nitrogen and potassium to an extent of about 80 percent and phosphorous 100 percent (even 110 percent).

The problem of more adequate manure utilization is of greatest importance, and in addition to the putting into effect of a number of commonly known measures for efficient storage and utilization of manure, in some isolated instances one is met with the necessity of far-reaching reorganization of farming economy in general. Here, as well as in many other problems of agricultural production, the question cannot be solved by means of some ready-made scheme, but must be handled by adopting a suitable system of appropriate measures which take into account actual conditions.

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Let us consider one instance, cotton-growing economy in Uzbekistan, which can be used to demonstrate how inadequately locally available nitrogen resources in an economy are being utilized. With 25 percent of the area cropped to alfalfa these are very substantial, but in actual practice a large portion of this nitrogen is lost, namely the nitrogen contained in the parts of alfalfa above the ground, and which exceeds the percentage of nitrogen present in root residues.

The gist of the matter is that bedding is not available; cereal grains have been driven off the irrigated area. By displacing grain, cotton has practically deprived itself of manure, since without straw manure preparation cannot be carried out properly. It is impossible to collect liquid excretions: they either flow off, or undergo decomposition on the premises, with most of the alfalfa nitrogen escaping into the air in the form of ammonia. Thus, lack of straw in an agricultural establishment greatly decreases the value of alfalfa as a nitrogen collector. How extensive such losses are is shown by the following computation. In Central Asia alfalfa yields four harvests, which corresponds to at least 100 centners of hay, or in 3 years, 300 centners. Since alfalfa hay contains 2.3 percent of nitrogen, this would amount to a total of 690 kilograms of nitrogen. Alfalfa is followed by cotton which takes up 6 fields in the nine-field crop rotation system. Each cotton field should receive in manure one sixth of the total alfalfa nitrogen, or 115 kilograms per year. Figures of manure utilization show however, that each hectare of cotton receives on the average not 115 but only 15 kilograms of nitrogen.

The huge loss of alfalfa nitrogen is being tentatively compensated by application of 40-45 kilograms of costly ammonium nitrate nitrogen, in place of utilizing nitrogen in the form of a good manure fertilizer.

The abnormal situation of nitrogen balance in cotton growing is made apparent by the following comparison. While even among the most highly industrialized countries of Western Europe of the total amount of nitrogen removed by crops (100 percent), there is returned (according to prewar data) 20-25 percent in mineral fertilizers and over 40 percent in manure, in Uzbekistan we have the opposite ratio, only up to 17.5 percent of nitrogen removed in the cotton crop is being returned in manure while mineral fertilizers must compensate for 48 percent of the removed nitrogen. (Occasionally the nitrogen portion returned in manure drops to 5 percent, as was shown for Andizhan Oblast' by Professor S. A. Kudrin.) This is the reason why Uzbekistan outranks France, Germany and Belgium in the amount of mineral fertilizer used per hectare, and, while competing in this respect with Holland for world wide leading position, produces lower yields of cotton (16 centners per hectare) than would have been obtained on using mineral fertilizers on a manure base (32 centners per hectare). This is the penalty for the lack of bedding and the lack of proper organization in the handling of manure.

I put forward in 1942 the proposal to introduce into irrigated areas grain crops yielding straw in such a proportion as to amply compensate in yield for the allocation to grains of cotton acreage by the increased crops obtained from the remaining acreage. Since grain crops produce in Uzbekistan two harvests within one vegetative period, while cotton yields but one, a large gain in both straw and grain would be thus realized.

The problem of a more adequate utilization of manure and other local resources throughout the entire Soviet Union is of tremendous importance. In order to give an idea of the possible part that manure could play in the general food balance, it should be pointed out that according to the calculations of Academician Ye. F. Liskun the total amount of manure that would be available annually in the USSR would equal the huge total of 1 billion tons if livestock were to be increased to the level where it fully met the national needs in animal husbandry products (computed on a per capita basis). Assuming that 70 percent of this amount would be used as fertilizer (taking into account incomplete manure recovery and part of it used for fuel), we have a potential utilization figure of possibly 700 million tons, which is equal to 3.5 million tons of nitrogen. This amount by itself would supply about 40 percent of the total nitrogen removed (8.2 million tons), as compared with the 20 percent available in 1937. If absolute values are taken, then the development of manure utilization to a quantity of 700 million tons per annum constitutes approximately a 3.5 fold increase in comparison with the 1937 figure. Taking into account that even before the war the actual utilization of manure in our country decreased to as low as 125 million tons annually (as in 1940), and naturally became even smaller during the war, it becomes readily apparent what it would mean for us to achieve an annual utilization of 700 million tons of manure. (See below for the alleviation that would result in the transportation of such large amounts of manure through effective utilization of green manures (in the form presently proposed) on more distant fields while concentrating the use of manure on nearer fields devoted to crops requiring intensive cultivation.)

We must once and for all put an end to underestimation of the tremendous importance of manure as the main basic link in the well-organized system of fertilizer application.

We must understand that without a radical departure from the present level of provisions made for supplying our fields with manure, it is futile even to contemplate establishment of normal correlations between intake and expenditure items in the balance of nitrogen and other nutrients in our agriculture; to improve systematically soil fertility, or to raise to an adequate level the yields on our fields.

At the same time it must be realized that in spite of its tremendous importance, manure can play a due part in the nitrogen balance of our agriculture, only if we increase sharply nitrogen intake through expanding the cultivation of clover, and other nitrogen fixing plants.

We must remember that by itself manure does not provide a new supply of nitrogen; it contains nothing that has not been previously a constituent of plants, and its utilization would be merely re-utilization, as factories reuse water of cooling systems, if there were not introduced into the manure a new supply of nitrogen from the clover. But manure is also a great source of nitrogen loss, especially in improper storage. Only through a simultaneous increase of nitrogen fixation by nitrogen fixating plants and improved management of manure can we attain liquidation of the unduly high deficit of our nitrogen balance with respect to biological nitrogen, that is, nitrogen fixed by the nodular bacteria of clover and other legumes. It can be estimated approximately that of the total nitrogen fixed by nodular bacteria of clover, one half remains in the soil (with the root residues while the other half passes with the hay into manure after having gone through the animal organism. Therefore, clover has a dual function in the nitrogen balance: first as a direct source of nitrogen intake for the soil in the form of root residues, and second, by increasing the nitrogen content of manure with that portion of the fixed nitrogen contained in the parts of clover (as well as of alfalfa and other forage legumes) which are above ground.

Thus, manure nitrogen, in the debit column of the balance, consists of two items, the new amount of nitrogen fixed by the legumes, and the nitrogen being returned to the soil a second time, which originally had been incorporated into the manure as a constituent of the bedding and through feeds other than clover and alfalfa hay. (An even more detailed subdivision is possible here. For example, when peat bedding is used, new amounts of nitrogen are also introduced through the manure; then, on utilization of the manure, a transfer of nitrogen and other nutrients utilized by the plants takes place from meadows to cultivated fields. We shall not further discuss these details here.)

On establishing the proposed balance of nitrogen it is necessary, therefore, to keep in mind the close association of the two intake items of legume nitrogen and manure nitrogen.

What acreage should then be devoted to legumes, in order to attain a satisfactory balance of nitrogen with the proposed average yield of 16 centners per hectare and the corresponding annual removal of 8 - 8.2 million tons of nitrogen? To answer this question it is necessary to determine how much nitrogen can be accumulated yearly by one hectare cropped to clover, alfalfa, lupine, etc.

Naturally, the amount of nitrogen accumulated by clover depends on the degree of development of the latter. Let us consider, however, what can be attained from a good growth of clover (assuming that we can supply the clover with phosphorus and potassium).

If the clover is of one year utility (two-year growth) then according to the fairly old data of Schultze (Breslau) it leaves in the root residues 177 kilograms of nitrogen (see compilation of earlier data in Reiner's book Ackerbaulehre (1933), pages 152 and 202) while according to the data of Werner and Weisk the figure is 152 kilograms. Since in the parts above ground there should be about 100 kilograms of nitrogen if the crop is a good one, then the total amount of nitrogen contained in the clover is 250 - 280 kilograms. Assuming that two thirds of this nitrogen is obtained from the air, we see that a hectare of good clover can assimilate about 160 - 180 kilograms. On this basis I reached the figure of 150 - 160 kilograms per hectare as an estimate for possible future balance of nitrogen.

Published material contains also other data according to which nitrogen assimilation by legumes takes place on a smaller scale; it is characteristic that Lyon and Bizzell, in carrying out these well-conducted experiments in the United States which took place over a period of 10 years, found that the amount of nitrogen fixed by red clover reached 182 kilograms per hectare annually (see below).

Hence, in making the proposed estimates, I can assume that clover accumulates 150 - 160 kilograms of nitrogen per hectare in one year, with the provision that the necessary potassium and phosphorus are provided. Under identical conditions we can take a similar figure (160 kilograms) for lupines, while considerably larger quantities of nitrogen are accumulated by alfalfa, which yields four harvests per summer with irrigation under Central Asian conditions.

Boussingault (1836-1838) had established even earlier that alfalfa can contain as much as 200 kilograms of nitrogen in the above-ground parts without being supplied with nitrogen fertilizer. In our Central Asian regions this amount has been found to be 227 kilograms (data of Ioffe, over a four-year period). The experiments of Lyon and Bizzel, previously mentioned, gave even a larger amount, up to 272 kilograms (on the average a ten-year period, while at the same time the soil content also increases in nitrogen. The extent of this increase is estimated differently by various researches. Thus according to data of the Akkavak Station for clay soils, alfalfa accumulated over a three-year period 1200 kilograms of nitrogen in a 40 centimeter soil layer, or an average of 400 kilograms per year. (See pamphlet of Gel'tser and Lasukova Effects of Crops on Soil Fertility, Tashkent 1934; also data of Ioffe and Zhorikov, given therein.) At Bayaut Sovkhoz there was found a 527 kilogram accumulation over 3 years in the cultivated layer alone. According to date of Shirabudinsk Station three-year alfalfa had accumulated in the soil 943 kilograms, and a five-year one 1219 kilograms of nitrogen. (It is, however, very difficult to obtain accurate results in determination of nitrogen increase, since it must be determined by differences in small samples against the presence of large nitrogen contents of the soil, and then is multiplied by an infinitely large quantity, i.e., ratio of soil weight per hectare to weight of Kjeldahl Sample.)

But on the other hand, American literature contains frequently lower values for nitrogen accumulated in the roots. (See review in article "Biological Nitrogen in Agriculture", Sotsialisticheskaya rekonstruktsiya sel'skogo khozyaystya, October 1935, page 126, and also article by Mishustin and Bernard in Khimizatsiya Sotsialisticheskogo zemledeliya 1935, No 11-12).

Therefore, we shall consider the probable annual accumulation of nitrogen to be 100 kilograms for alfalfa roots and 200 kilograms for the aboveground portions, a total of 300 kilograms per year. However, as shown above, under Central Asian conditions it has been necessary until now to take into account the fact that most nitrogen of above-ground portions of alfalfa is lost, and only the root residues of nitrogen are certain to escape losses. In the future when grains are introduced in the crop-rotation system of cotton cultivation, the conditions under which manure is produced and stored should improve.

Among forage grasses we can also consider the vetch and oat mixture; but here the amount of nitrogen accumulation cannot be large because of the short growing period of the vetch and also because of its dilution with oats.

We frequently sow vetch with oats due to lack of clover seed, but when clover seed is available it would be much more advantageous to have a one-year stand of clover than of vetch with oats. The advantages of clover as compared with a vetch-oat mixture are primarily determined by the fact that clover, because it is sown during the preceding year, begins to grow much earlier, and with the first days of spring starts to assimilate carbon, supplying carbohydrates for its own use as well as for tubercle bacteria in the roots, thereby effecting nitrogen fixation. On the other hand a vetch-oat mixture requires time for the ground to dry sufficiently to permit use of agricultural machinery; then one must wait until the shoots appear, while assimilation begins to outweigh the respiratory processes of the young plants. Then also, although vetch is a nitrogen collector, oats are a nitrogen consumer, so that the final results appear most uncertain, insofar as incorporation of nitrogen into the soil is concerned. Observations have been made which showed all the nitrogen recovered from the air by the vetch to be found in the above-ground portion of a vetch-oat mixture, and passing from there into manure which was later applied to other crops, while the autumn-sown crop which followed immediately the vetch-oat mixture, could have found the soil even poorer in nitrogen. Such would be the case where oats remove more nitrogen from the soil than the vetch has time to accumulate in its root residues.

Hence there is the possibility of instances where all nitrogen increase due to vetch would be found in above-ground parts and not in the soil. Therefore, clover, even of one-year stand, is a much better precursor of winter crops than vetch with oats. An example of general nitrogen balance improvement in which an annual legume was combined with cereal grains and resulted in soil nitrogen decreases, is cited in the previously referred to publication of Lyon and Bizzel.

Since their results are interesting in many respects, it is instructive to consider them in some detail. (Journal of the American Society of Agronomy, 1934, No 8).

The experiment was conducted as follows: Over a 10 year period different legumes were sown alternatively with cereal grains, following the two-field type crop-rotation system, and all harvest yields were analyzed; the amount of soil nitrogen was also determined before and after the experiment. The average figures are shown in the following table (kilograms of nitrogen annually, per hectare):

	Increase or Decrease of Soil Nitrogen	Nitrogen in Above-ground Portion	Total Nitrogen Increase
Red Clover	66.5	116.0	182.5
Swedish Clover	74.4	95.6	170.0
Alfalfa	75.9	224.3	300.2
Sweet-clover	52.5	151.2	203.7
Vetch with Wheat	12.1	69.1	81.2
Mixture of Red and Swedish Clover	72.2	131.5	203.7
Sweet Clover and Vetch	51.2	143.8	195.0

Soybeans	- 5.2	132.7	127.5
Peas with Oats	- 4.0	61.5	57.5
Lentils	-12.5	83.7	71.2
Alfalfa Continuous Cultivation	63.1	271.9	335.0

Here it is of interest to note that in alternation of annual legumes and grains the soil of a given area can, on final analysis, lose a portion of nitrogen, and all excess nitrogen derived from the air is found in the above-ground plant portions (together with nitrogen taken from the soil).

But if this result lowers the value of vetch as a crop preceding a winter crop in the total balance one must, of course, take into account the nitrogen found in the above-ground portion of the vetch. One may assume that vetch sown in admixture with oats, yields a 50 to 80 kilogram increase of nitrogen taken from the air.

Probably, an increase of the same order can be assumed as being the minimum in the case of seed legumes, the acreage under which should be considerably increased in this country, since they afford a dual advantage over other spring crops - they do not require nitrogen fertilizers, contain in the seeds twice as much protein as cereal grains, and their straw is much richer in protein than the straw of cereal grains; hence they can constitute an important source for supplementing the total deficiency of proteins in food and feed balance which is present in our country (especially within regions which have suffered from the German occupation). The genus of leguminous plants is rich in species and makes it possible to select varieties best adapted for any given conditions of soil and climate. Thus in the south there is possible cultivation of beans, soybeans and peanuts; in the north, peas and lentils are of great importance; in the forested steppe belt they are supplemented by horse beans, and in the arid south-eastern zone chick-peas and vetchlings are of primary importance. (In addition to being spring crops some legumes can be grown for fallow. Among these are lentils, which ripen in the chernozem belt before autumn sowing of winter crops, and also such late crops as beans, when winter crops are sown in-between rows (45-50 centimeters) prior to harvesting of the beans. Where the beans cannot be grown because of excessively dry climatic conditions, it is worthwhile to try "sweet" lupines (as a seed crop) and chick-peas (tall varieties). Unlike other crops, these plants partially compensate the nitrogen decrease of fallow land and also loss of moisture, if a sufficiently tall stubble is left on harvesting, so as to ensure snow retention).

It must be noted that the ten-year experiment of Lyon's conducted to produce nitrogen accumulation by means of clover, yielded results similar to those figures which we took as a basis of our approximate computations relative to nitrogen accumulation by means of this crop. And if we assume that one hectare of good clover supplied with potassium and phosphorus can provide 150 - 160 kilograms of nitrogen in one year, counting the nitrogen of clover hay as well as that of the root residues, it follows that 200 thousand hectares of clover can, on proper management, fix 30 thousand tons of nitrogen per year, that is, be equivalent to the output of a fairly large industrial nitrogen fixation plant. The same can be said of lupines, as well, but alfalfa, in yielding four harvests per summer, can provide twice as much as clover. Naturally, for biological nitrogen to acquire due significance in nitrogen balance, it is indispensable that proper crop rotation be introduced and inculcated throughout. We have seen that in Western Europe adoption of crop rotations with 25 percent of clover resulted in a two-fold increase of grain-crop yields, and an even higher increase of overall field crop production. True, the primary part in that case was played by the four-field crop rotation (Norfolk) system, while the predominant system in our country is presently the eight-field one, but we usually have clover for two years for 25 percent of the acreage. Naturally, in order to devote more space to clover it would have to be introduced into the crop rotation system not only by decreasing the amount of fallow land (for example, down to 12.5 percent) but also by increasing somewhat the acreage under cultivation within the chernozem belt (see above). If the total acreage under cultivation were to be raised to 160 million hectares, under an eight-field crop rotation system, the acreage cropped to legumes could equal 40 million hectares, which in the case of clover would correspond to an accumulation of 6.4 million tons of nitrogen, that is, would cover by biological means three-fourths of the total future nitrogen requirements. (Eight-field crop rotation, with two-year clover, two fields of each winter grain and spring grains and one or two fields of row crops, would be linked genetically to the classic rotation of crops, namely the Norfolk four-field system (row crop, spring grain, clover, winter grain). The next link was provided by the Danish eight-field system in which saving of clover seed was effected by introducing two-year clover. The following sequence was then obtained: row crop, spring grain, clover, clover, winter grain, row crop, winter grain, spring grain. Due to climatic conditions in our country it is necessary to replace one of the row crops by fallow, retaining the other essential features of the crop rotation. Even though the sequence is altered somewhat depending upon whether clover is grown prior to autumn-sown grain or to spring-sown grain, the percentage of area under clover in the basic rotation usually would still not exceed 25, which is characteristic of rotation of the grain crop type. Only when farming practice includes a second (additional) rotation system for the supply of livestock feed, it may compute 60 percent or more under forage grasses, that is, assume the character of a field-grass rotation system. But basic rotations are usually of the grain-crop type, with the exception of the dry Southeast where the fallow-row crop type (without perennial grasses) prevails). But since for the time being, only introduction of annual legumes of the seed-yielding type may be considered for the Southeast, and not of clover and alfalfa, we shall confine ourselves to a more limited goal - the gathering by legumes of one half for future nitrogen removal by crops, or 4.1 million tons of nitrogen, which can be attained by allocating to clover and alfalfa 27 million hectares.

Of the total amount of nitrogen fixed by legumes (4.1 million tons) one half (2.05 million tons) would remain directly in the soil, with the root residues, while the other half would be supplied to the soil in manure.

On the whole, we can outline in a general manner the following proposed system of nitrogen balance for agriculture in the Soviet

Union, based on first priority allocation of synthetic nitrogen to meet requirements of more valuable industrial crops which would raise crop yields for the entire acreage under cultivation up to 16 centners of grain per hectare (and a corresponding increase of other crop yields).

Prospective Plan of Nitrogen Balance for USSR Agriculture

			Total	
	In 1000 Tons	In Per-cent	In 1000 Tons	In Per-cent
I. Nitrogen removal from a 160-million hectare area in crop yields of 16 centners of grain per hectare and a corresponding yield level for other crops	8200	100.0	8200	100.0
II. Return:				
(1) Nitrogen of mineral fertilizers	1300	15.9	1300	15.9
(2) Nitrogen fixed by legumes (over an area of 27 million hectares	4100	50.0		
Including:				
(a) In root residues	2050	25.0	2050	25.00

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(b) Nitrogen of above-ground portions returned to the land with manure	2050	25.0	-	-
(3) Manure Nitrogen (700 million tons)	3500	42.7	3500	42.7
Including:				
(a) Nitrogen in above-ground portion of legumes	2050	25.0	-	-
(b) Nitrogen withdrawn from the soil by the plants, and returned in manure re-utilization	1450	17.7	-	-
Total	-	-	6850	83.6
III. Deficit, compensated by activity of free-living nitrogen collectors	-	-	1350	16.4

This tabulation of items of the prospective nitrogen balance shows, in our opinion, by what route and in what general direction we must proceed to solve the problem of supplying our agriculture with nitrogen, striving essentially to alter our nitrogen balance so as to eliminate its excessive deficit, and to ensure further yield increases as well as greater soil fertility. This general direction, in our opinion, must be one toward more biological nitrogen, primarily clover and alfalfa nitrogen. It is precisely in that direction that we perceive the solution of the nitrogen problem concerning our most important crop - cereal grains. At the same time, closely connected with this primary bid for biological nitrogen, there looms in the foreground the tremendously important question of manure utilization, which must ensure gathering into the agricultural cycle approximately one half of the total amount of nitrogen fixed by clover and alfalfa.

To delineate more clearly the characteristics of the path to be followed in solving the problem at hand, let us compare the corresponding items of our actual prewar nitrogen balance, according to 1937 data, with those of the outlined, prospective plan (see Table).

In Million Tons of Nitrogen

Balance	Removal	Return				
		Mineral Fertilizers	Clover		Manure	Deficit
1	2	3	4	5	6	7
1937	4.90	0.20	0.20	0.20	0.90	3.40
Prospective Plan	8.20	1.30	2.05	2.05	1.45	1.35
Difference	3.30	1.10	1.85	1.85	0.55	- 2.05

Column 5 common to both clover and manure includes nitrogen of above-ground portions of clover and other legumes, incorporated into the soil with the manure. Column 4 shows the nitrogen of root residues of clover (and alfalfa). Column 6 includes that portion of nitrogen in manure which constitutes re-utilization (nitrogen gathered from the soil by the plants and returned to the soil through manure).

Thus, according to the prospective plan the increase of nitrogen removal by 3.3 million tons, is compensated only to one third by a corresponding increase in synthetic nitrogen requirements; the remaining two thirds of the additional removal must be compensated through an increase of other sources of nitrogen intake, primarily of biological nitrogen and manure nitrogen. These same sources must also yield a further amount of approximately 2 million tons of nitrogen to decrease the initial deficit of the nitrogen balance.

Insofar as that portion of manure nitrogen is concerned which consists of nitrogen gathered from the soil by plants and returned with the manure (Column 6), its increase must be secured by increasing the amount of bedding and feed, resulting from increased yields of grains and non-leguminous feed crops, and also by decreasing nitrogen losses in manure storage, and by more efficacious manure utilization.

According to the plan for a nitrogen balance given above, as stated previously, only the main intake items are considered, while certain additional sources, which must also be utilized, have not been taken into account. Even though hitherto they had no decisive part in solving the nitrogen problem as a whole, these secondary sources nevertheless deserve serious consideration in the future.

This must be borne in mind in the immediate future because there has taken place a sharp decrease in basic sources of biological nitrogen intake due to a number of causes caused by the war, which include a smaller number of livestock (especially within areas of former German occupation), decrease of manure production connected therewith, and destruction of clover crops and consequent inadequate supplies of clover seed. The last has caused in many instances a decrease in acreage cropped to clover, etc. It must also be remembered that the full effect of those measures which are going to be taken to make a basic improvement in the balance of nitrogen by increased planting of clover, will not be felt immediately. The fact is that in our system of perennial clover cultivation, there is a time interval of 4 - 5 year duration between sowing of clover and harvesting of that crop, whose growing is utilized for foil amelioration. It is true that the effect of nitrogen-enriched manure derived from clover may be felt before that, but not sooner than three years after sowing of the clover. Moreover, only on gradually passing from field to field of the rotation system can the clover produce an overall effect on yield increase.

Therefore, an increase of acreage under clover effected in 1946, would give a yield increase for subsequent crops planted only in 1949-1950. To ensure expansion of acreage cropped to clover it is necessary first of all to develop vigorously and rapidly measures for increasing the output of seed at sovkhozes and kolkhozes located within given areas, since it is lack of clover seed and not of average that limits at present the development of our clover-growing program.

Naturally the increased accumulation and utilization of manure, no matter how much effort is devoted to this measure, will also progress only gradually, concurrently with the rehabilitation and further development of animal husbandry, and expansion of feed resources, that is, primarily of the growing of clover.

In connection with what has been said at the present time, of especially great importance in our country are all those additional resources and potentialities, that can be drawn upon for supplying the intake items of the nitrogen balance. Let us briefly consider some of them.