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Modern science-based fertilizer systems. Determining mineral fertilizer requirements.

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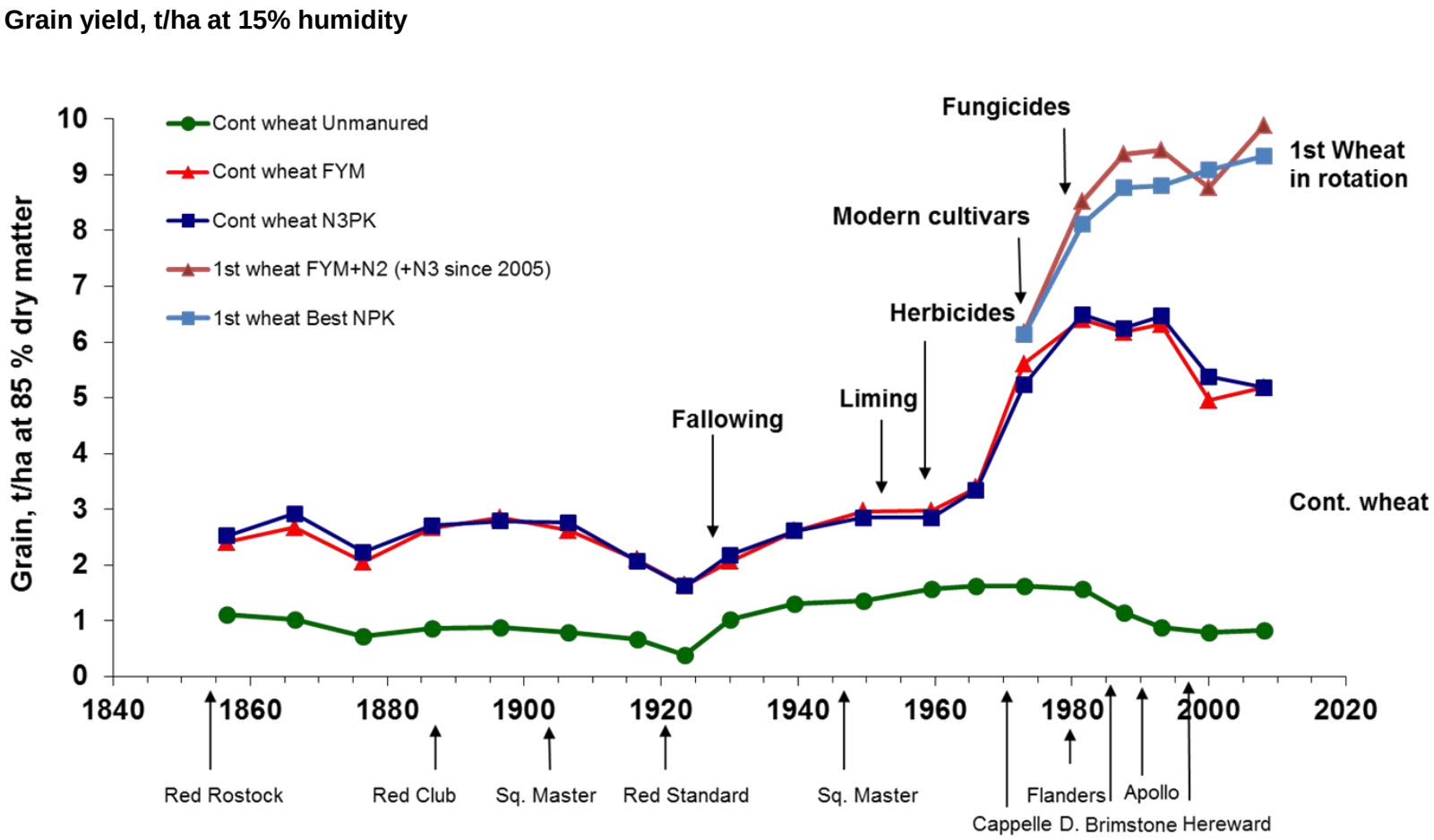
History of farming systems and fertilizer application

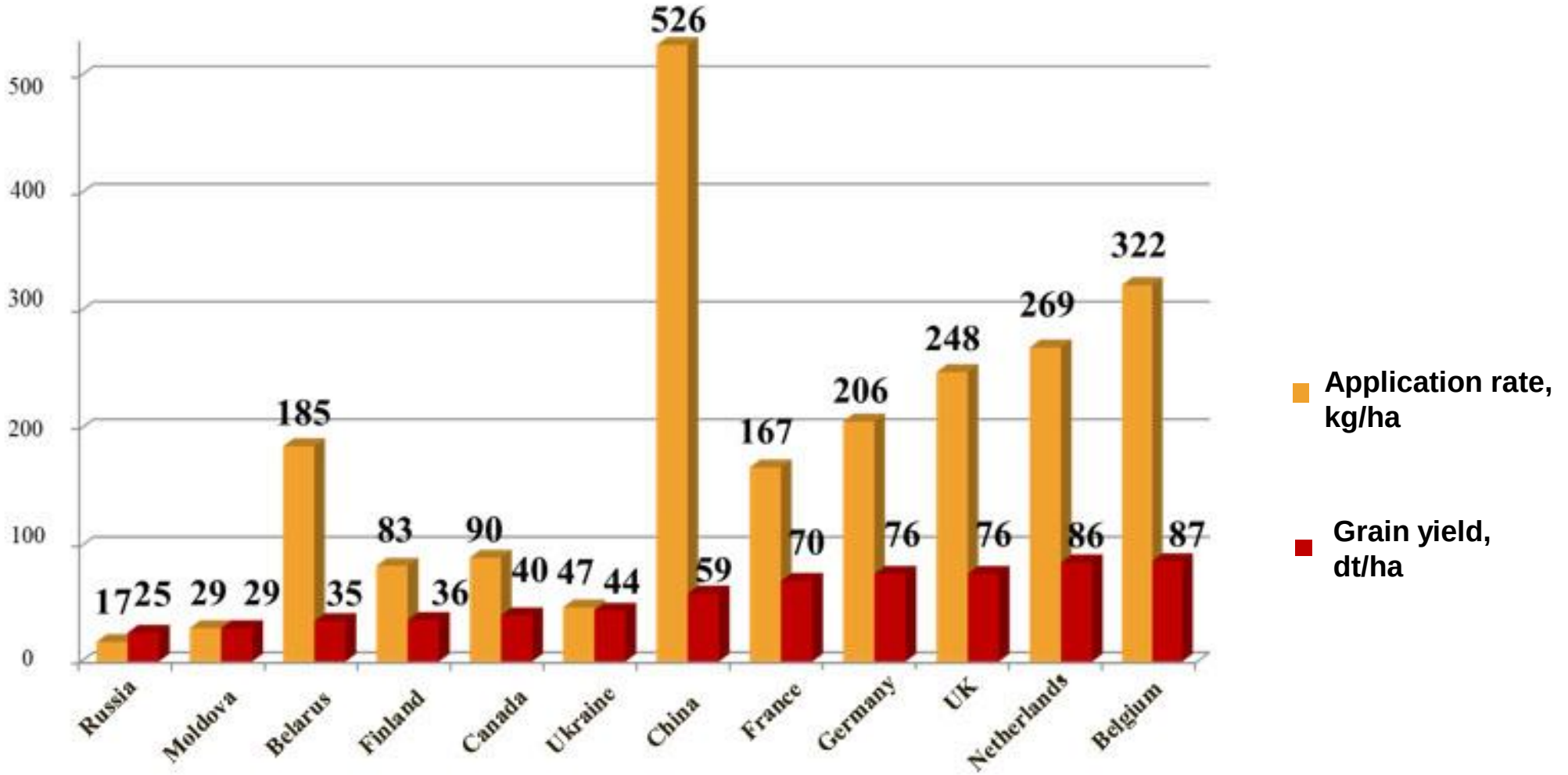
- **The primary goal of agriculture** is to supply food for the world's population
- Slash-and-burn and land rotation systems: grain yield of ≈ 4 dt/ha;
- Medieval three-field system: **fallow — winter crops — spring crops**: yield increase up to 6–7 dt/ha because of fallow, allowing the soil to have a rest period;
- Rotational system developed in England in the 18th century. Norfolk system: **row crops — spring crops — clover — winter crops**: yield increase up to 16 dt/ha;
- Agricultural intensification with the use of mineral fertilizers in early 20th-century Europe made it possible to increase grain yield to 30 dt/ha;
- The Green Revolution in the second half of the 20th century: the advent of intensive technologies and complex application of mineral and organic fertilizers, chemical ameliorants, and plant protection products, resulting in grain yield increases of ≥70–80 dt/ha.

Long-term experiments at Rothamsted Research, 1843
Broadbalk: harvests, varieties, and modifications



Introduction of new winter wheat varieties

Application of mineral fertilizers and grain yields around the world



Objectives of a fertilizer system

- **A fertilizer system** is a set of science-based measures for applying organic fertilizers, mineral fertilizers, and chemical ameliorants to agricultural crops, taking into account the biological characteristics of crops and their varieties, soil fertility, climate, crop rotation type, preceding crops, fertilizer properties, and other factors.

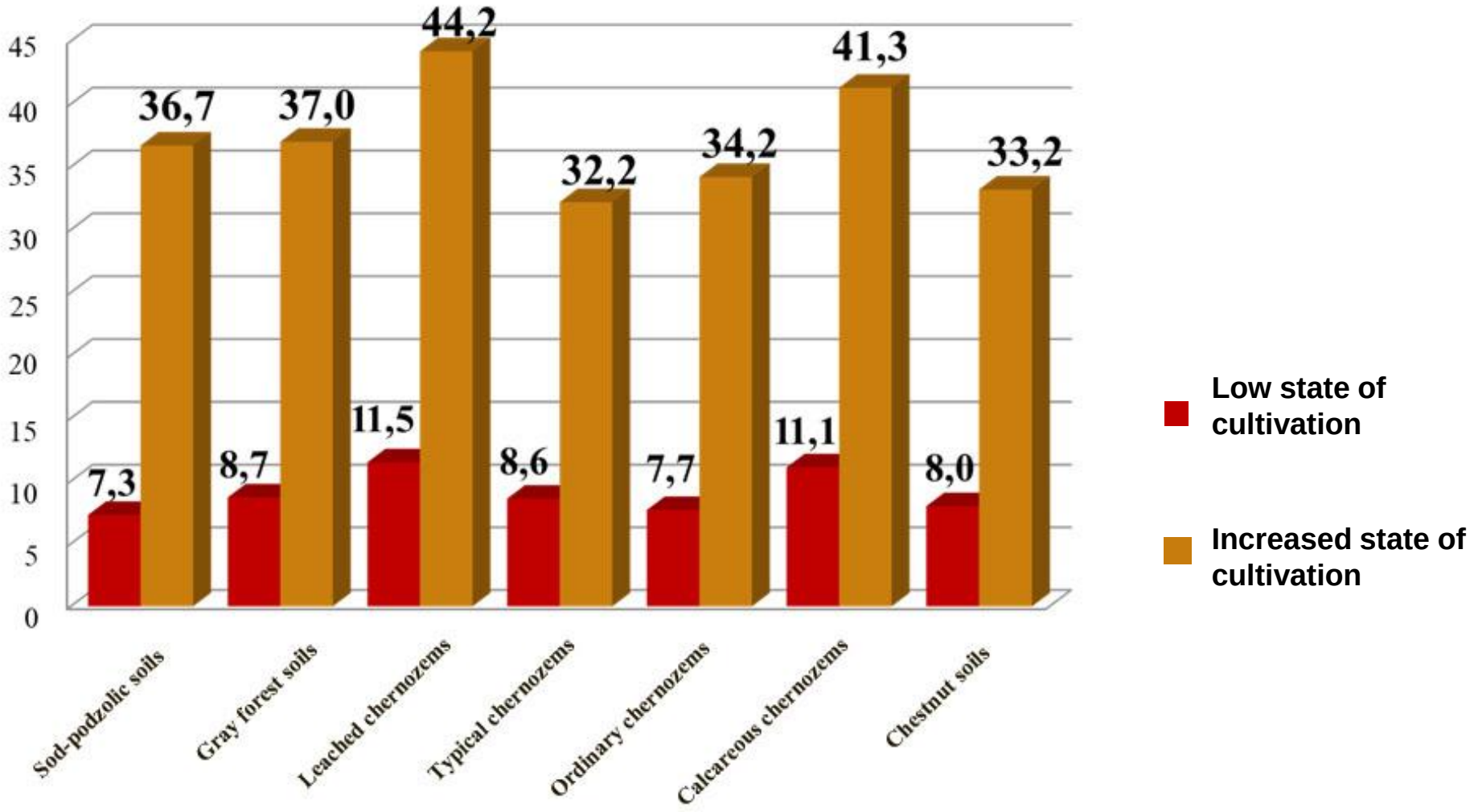
Objectives:

- Providing plants with macro- and micronutrients during all growth and development phases;
- Increasing soil fertility through a healthy nutrient balance and soil cultivation as the basis for future yield increase;
- Improving the quality parameters of crop production (protein and gluten in grain, starch in potato tubers);
- Prevention of environmental pollution by agrochemical residues;
- Increasing the economic efficiency of agricultural production.

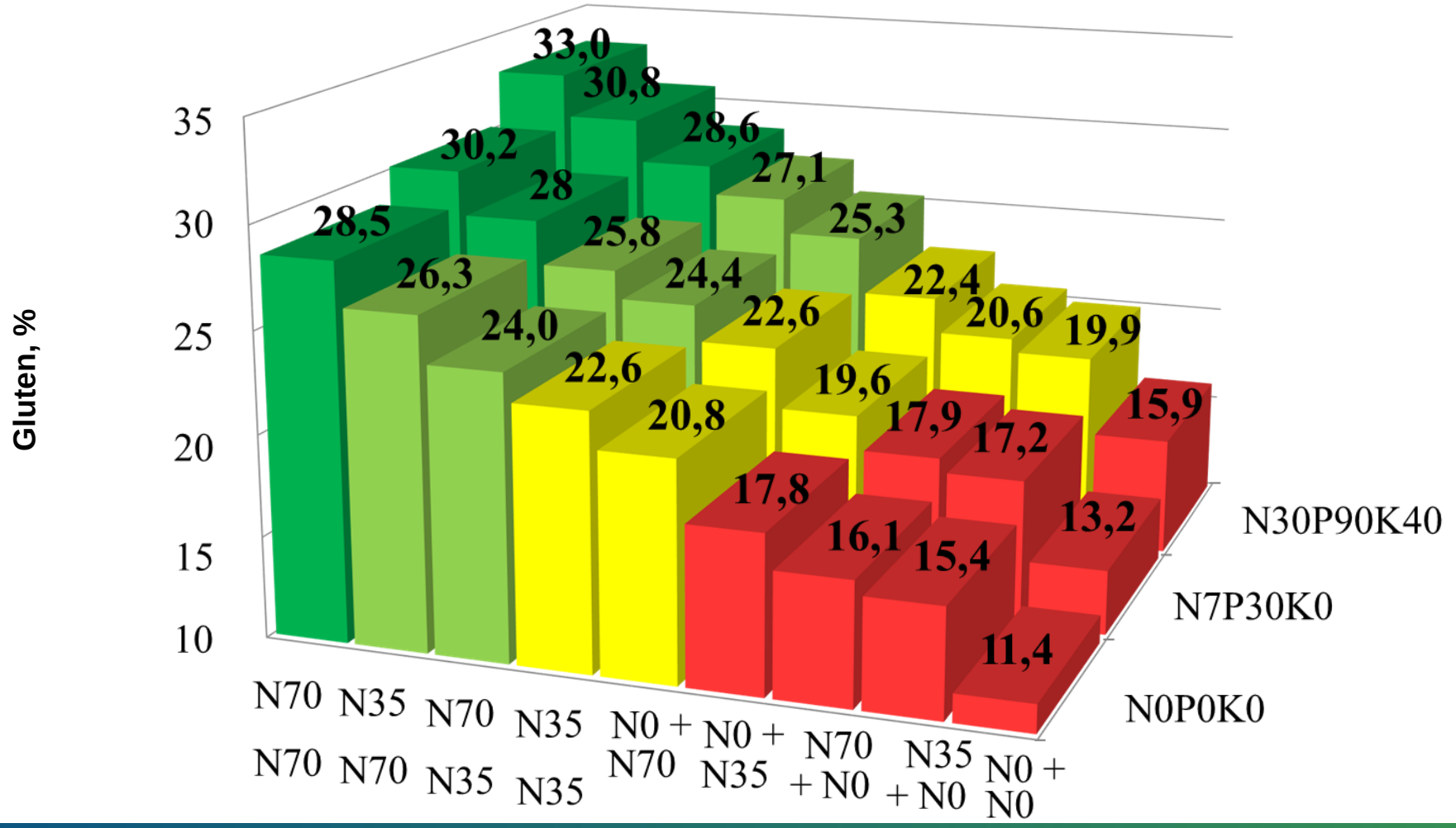
Nutrient balance in Russian agriculture, kg/ha (Pryanishnikov Institute of Agrochemistry)

Years	Supply with fertilizers			Crop removal	Balance
	mineral	organic	total		
Nitrogen					
1971–1995	24	16	40	33	7
1996–2010	9	5	14	31	-17
2011–2018	10	4	14	42	-28
Phosphorus					
1971–1995	18	7	25	14	11
1996–2010	3	2	5	9	-4
2011–2018	4	2	6	13	-7
Potassium					
1971–1995	14	16	30	37	-7
1996–2010	2	2	4	22	-18
2011–2018	3	3	6	43	-37

Effect of the state of cultivation of Russian soils on winter wheat yield, dt/ha



Effect of fertilizers on gluten content in winter wheat grain, for sunflower; Lukyanenko National Grain Center, Krasnodar



Total mineral fertilizer requirement in Russia, mln tons (Sychev, Shafran, 2020)

Industrial agriculture development scenarios	Nitrogen	Phosphorus	Potassium	Total
Business as usual*	2.3	2.3	2.3	6.9
Base case**	4.7	3.5	3.5	11.7
Best case***	5.3	4.3	4.3	13.9

The business as usual scenario provides:

- Receiving 100 mln tons of grain and 25–30 mln tons of feed (feed units)
- Increasing areas under agricultural crops up to 80–85 mln ha

The base case scenario provides:

- Receiving 120–125 mln tons of grain and 60 mln tons of feed units for arable land
- Increasing the arable area up to 100–105 mln ha
- Decreasing imports of agricultural raw materials and food

The best case scenario provides:

- Annual average gross grain yield: 145–155 mln tons
- Area under grain crops: at least 50 mln ha
- Grain yield: 27–30 dt/ha
- The proportion of arable areas where innovative technologies are used: at least 75%
- Grain exports: 40–60 mln tons per year

Forecasted nutrient balance in Russian agriculture, kg/ha of arable land (Shafran, 2021)

Industrial agriculture development scenarios	Supply with fertilizers		Crop removal	Balance
	mineral	organic		
Nitrogen				
Business as usual	20	4	41	-17
Base case	41	6	47	0
Best case	46	7	53	0
Phosphorus				
Business as usual	20	2	15	7
Base case	30	3	17	16
Best case	37	3	18	22
Potassium				
Business as usual	20	4	43	-19
Base case	30	5	47	-12
Best case	37	8	53	-8

Conclusion

- Russia has all the capabilities to implement the Food Security Doctrine. The findings of numerous long-term field trials provide compelling proof of this.
- Geographical network of fertilizer application and regional experience. Between 2016 and 2018, mineral fertilizer application in the Central and North Caucasian Federal Districts averaged about 100 kg/ha, resulting in grain yields of approximately 40 dt/ha. Such yields are achieved in Canada with a similar application rate of mineral fertilizers.
- Simultaneously, considerable focus should be given to improving soil fertility in the non-chernozem zone.

Conclusion

- The presented studies suggest that the mineral fertilizer requirement of 13.9 mln tons under the best case scenario is realistic, since it accounts for only around 60% of their production.
- To maximize the effect of fertilizer costs, the existing regulatory and reference base must be improved, as major changes are continually taking place in industrial agriculture. New varieties of agricultural crops are being developed, and cultivation techniques, soil fertility, and climate are changing. Thus, mineral fertilizer efficacy studies should be conducted on a regular basis.

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Thank you!