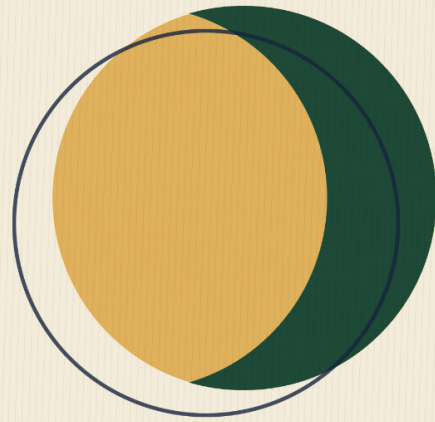




**Fertilizer Efficiency in
Four Grain Systems:**
The North American Input
Advantage

October 2026

EXECUTIVE SUMMARY:

Sixty-three years of FAO data on cereal yield and fertilizer were used to analyze four large grain systems for synthetic nutrient efficiency and input price sensitivity.

- The United States turns a kilogram of applied nutrient into four times as much grain as China and four and a half times as much as Brazil.
- Canada and the US run at roughly a third of Brazilian and Chinese nutrient intensity. A tonne of grain carries 13 kg of applied nutrient in the United States and 32 kg in Canada, against 53 kg in China and 62 kg in Brazil.
- The United States applies the least nitrogen per hectare of the four, 59 kg, and harvests the most grain per hectare. Its marginal response since 2001 is 8.6 times China's.
- China cut its application rate 20% from the 2014 peak while yield rose a further 8%, demonstrating at national scale that a fifth of its fertilizer was buying nothing.

For a farmland allocator, North American cropland carries materially less exposure per tonne of output to a fertilizer price shock than either intensification market.



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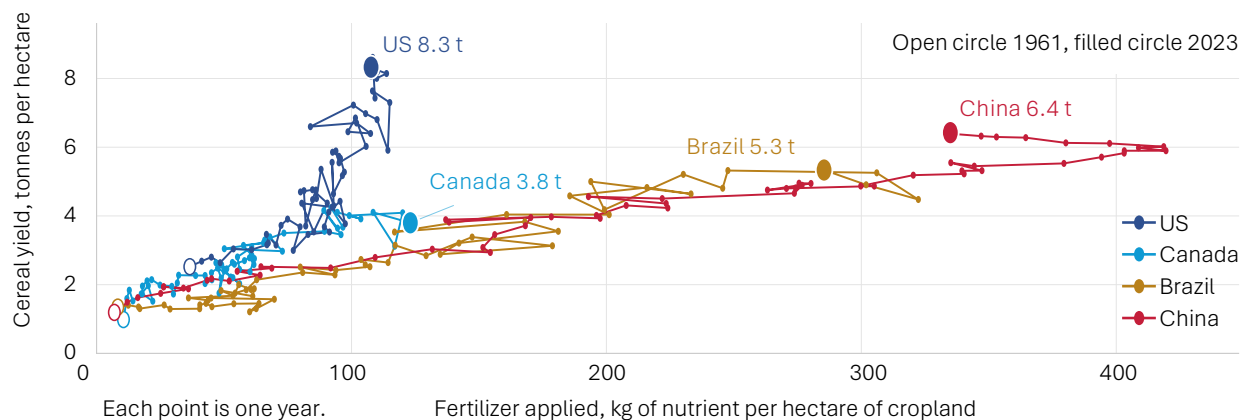
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SIXTY-THREE YEARS OF YIELD AND FERTILIZER ANALYSIS: US, CANADA, BRAZIL AND CHINA:

Chart 1: US, Canada, Brazil and China – 1961 to 2023

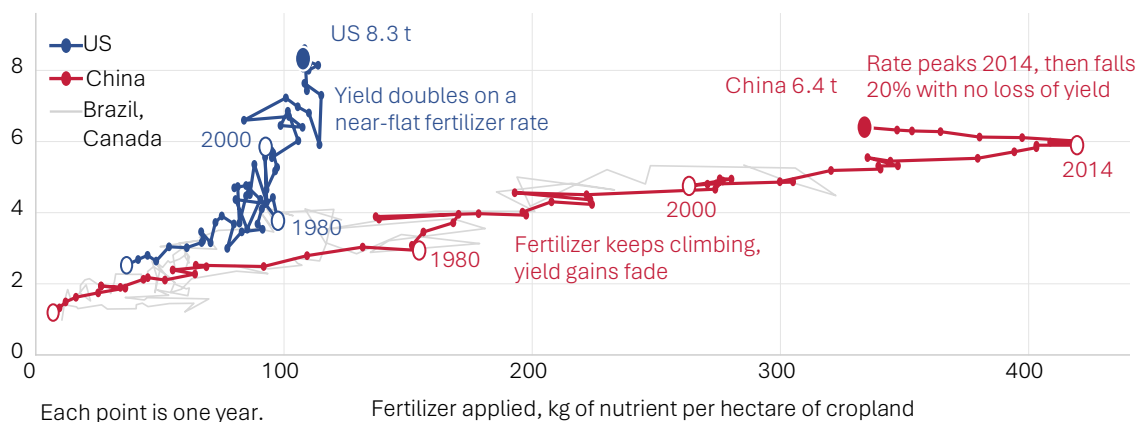


Source: FAO, via Our World in Data.

Chart 1 plots each market's annual pair of values, fertilizer applied against cereal harvested, from 1961 to 2023. Every line starts between 1.0 and 2.5 tonnes per hectare on under 40 kg of nutrient, and they end in very different places. The two North American tracks climb steeply and stop short of 130 kg of nutrient. Brazil and China run sideways in their later years, adding nutrient much faster than grain and finishing beyond 280 kg. The United States is the only one of the four whose grain per kilogram of nutrient is higher now than in 1961, up 16% against declines of 74% in Canada, 87% in China and 90% in Brazil.

THE TWO EXTREMES:

Chart 2: United States and China Only



Source: FAO, via Our World in Data.

Chart 2 highlights the US versus China in efficiency. The American line climbs upwards and the Chinese line stretches to the right. While China's application rate peaked in 2014 at 419 kg per hectare and has since fallen 20%, the current difference in efficiency of fertilizer use is noteworthy.

Table 1: Efficiency measures, three-year averages to 2023

	US	Canada	Brazil	China
Cereal yield, t/ha	8.21	3.68	4.91	6.38
Fertilizer, kg/ha cropland	108	116	303	339
Grain per kg nutrient, t	0.076	0.032	0.016	0.019
Nutrient per tonne grain, kg	13.2	31.6	61.8	53.2
Grain per kg vs. 1961	+16%	-74%	-90%	-87%
Marginal response, t/kg	0.063	0.017	0.011	0.007
Rate vs. own peak	-6%	at peak	-11%	-20%
Nutrient per tonne vs. 2000	-18%	+53%	+57%	-5%

Source: FAO nitrogen, phosphate and potash application series, via Our World in Data. Cereal yield is per hectare of cereal area; fertilizer is per hectare of all cropland. Marginal response is the OLS slope of yield on application rate, 2001 to 2023.

Table 2: Nutrient composition, kg per hectare of cropland, 2023

	US	Canada	Brazil	China
Nitrogen (N)	59.1	73.2	90.9	192.4
Phosphate (P2O5)	23.7	29.4	70.0	73.4
Potash (K2O)	24.8	20.5	124.4	69.1
Total	107.7	123.1	285.3	334.9

Source: FAO nitrogen, phosphate and potash application series, via Our World in Data.

US AND CANADA: THE EFFICIENCY PATH

The American record is one of decoupling. Since 1980 US cereal yield has doubled, from 4.2 to 8.2 tonnes per hectare, while the application rate rose 14%. Since 2000 alone, yield is up 41% on a 16% rise in nutrient, and the nutrient required per tonne

of grain has fallen 18%, from 16 kg to 13 kg. The rate itself peaked in 2013. The United States applies the least nitrogen per hectare of the four, 59 kg versus 73 in Canada, 91 in Brazil and 192 in China, while harvesting the most grain per hectare of any of them. Its marginal response since 2001, 0.063 tonnes for each additional kilogram, runs 3.6 times Canada's, 5.7 times Brazil's and 8.6 times China's. This is a yield curve driven by genetics, seed placement, drainage and nutrient timing rather than by the quantity applied. Measured against the nutrient actually added since 2000, the United States gained 16 tonnes of yield for every additional 100 kg of nutrient applied per hectare. China gained 2.3 tonnes, Canada 1.5, and Brazil 1.

Canada is the second most efficient of the four, and the difference to the Chinese and Brazilian markets is wide. A Canadian hectare carries 116 kg of applied nutrient against 303 in Brazil and 339 in China, close to a third of their intensity. Per tonne of grain produced, Canada uses 32 kg against Brazil's 62 and China's 53. On the nutrients whose prices track natural gas and phosphate rock the ordering holds: Canada applies 73 kg of nitrogen and 29 kg of phosphate per hectare, against 91 and 70 in Brazil and 192 and 73 in China. China applies 2.6 times Canada's nitrogen rate. Canada also carries the second highest marginal response of the four, 0.017 tonnes per additional kilogram against 0.011 in Brazil and 0.007 in China.

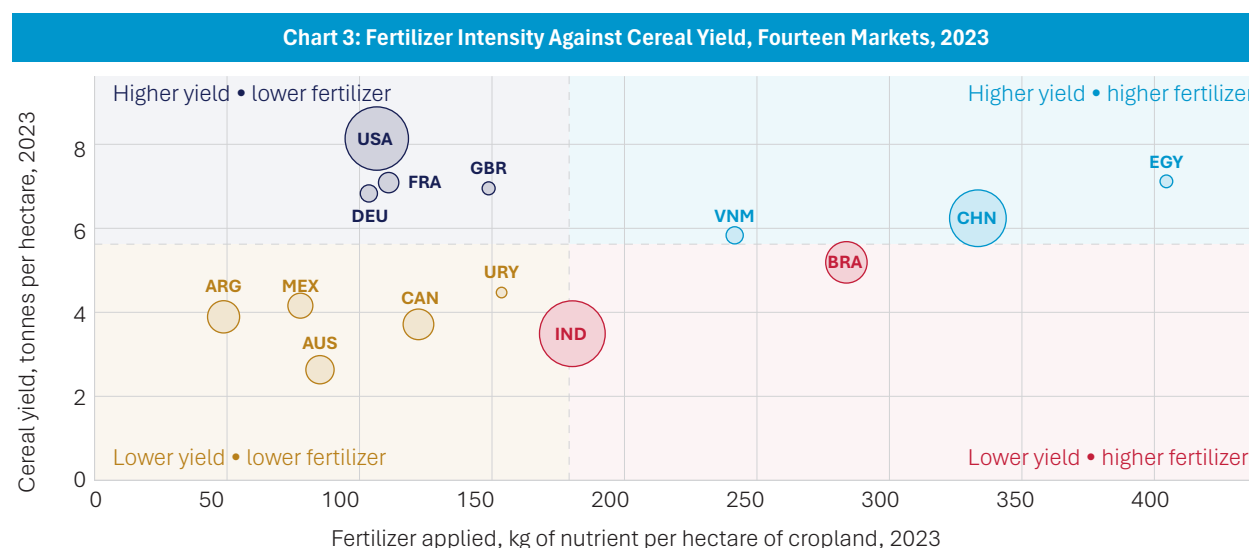
BRAZIL AND CHINA: THE INTENSIFICATION PATH

Brazil has posted the fastest yield growth of the four since 2000 and paid for it in fertilizer volumes. Cereal yield is up 73% over that period, a better record than any of the others, on a 171% rise in the application rate. Nutrient per tonne of grain rose 57% to 62 kg, the highest of the four. Composition explains a good deal of it. Brazilian cropland is weighted heavily to soybeans, which fix their own nitrogen, so the nitrogen rate of 91 kg per hectare is modest against the total; phosphate at 70 kg is three times the US rate, and potash at 124 kg. Brazil applies more potash per hectare than the United States applies of all three nutrients combined. Cerrado soils fix phosphorus and carry low native fertility, so a meaningful share of that application corrects a soil constraint. Brazil also imports the great majority of its fertilizer, which puts the whole system on a US dollar-priced input base.

Chinese cereal yield compounded at 2.6% a year from 1961, the fastest of the four over the full period, reaching 6.4 tonnes per hectare, above Brazil. It was generated with the heaviest nutrient load in the group: 339 kg per hectare, of which 192 kg is nitrogen alone, 3.3 times the US nitrogen rate and more than the entire US application of all three nutrients. Marginal response since 2001 is 0.007 tonnes per kilogram, the lowest of the four, and that is what the long sideways stretch of the red line in Chart 2 represents. Following the 2015 action plan targeting zero growth in fertilizer use, the Chinese rate has fallen 20% from its 2014 peak while yield rose a further 8%. China has demonstrated at national scale, on its own cropland, that a fifth of its fertilizer was buying nothing. Brazil's recent decline follows the price spike rather than a policy, and may not persist.

GLOBAL COMPARISON:

Chart 3 uses the same two measures for fourteen global markets.



Marker area is proportional to cropland area. Dividers held at 180 kg per hectare and 5.8 tonnes per hectare.

Source: FAO, via Our World in Data.

The United States sits with France, Germany and the United Kingdom in the upper left, higher yields with better fertilizer intensity. Egypt, China and Vietnam occupy the upper right, where a comparable yield has been generated with far more nutrient. Egypt is the clearest case, harvesting 7.4 tonnes per hectare on 407 kg, nearly four times the American rate for a smaller crop. Brazil and India occupy the lower right. Canada, Australia, Uruguay, Mexico and Argentina share the lower left, at rates running from 49 to 154 kg.

WHAT IT MEANS FOR FARMLAND INVESTORS:

Canada and the US are structurally less exposed to fertilizer prices than markets like China or Brazil. A US cereal margin carries 13 kg of nutrient per tonne of output and a Canadian one 32 kg, against 53 in China and 62 in Brazil. The per-hectare gap is wider still: North American growers work at about a third of the nutrient intensity of their Brazilian and Chinese counterparts, so a given move in urea or DAP passes into a North American operating margin at a fraction of the force. That is what the 2021 and 2022 gas-driven spike demonstrated in practice. Yield growth on both sides of the border now comes from genetics and agronomy rather than from a proportionate rise in a volatile input bill, which supports the real return floor on North American cropland.

North American farmers work at roughly one third of Brazilian and Chinese nutrient intensity.

A move in urea or DAP reaches North American farming margins at a fraction of the force compared to China or Brazil



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