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FAOSTAT ANALYTICAL BRIEF 95

# Cropland nutrient balance

## Global, regional and country trends

## 1961–2022

>> FAO Statistics Division

## HIGHLIGHTS

- → **At the global level, the cropland nutrient surplus in 2022 was 82 million tonnes (Mt) of nitrogen (N), 7 Mt of phosphorus (P), and 8 Mt of potassium (K) corresponding to 52 kg N per ha, 4 kg P per ha, and 5 kg K per ha of cropland.**
- → **The Americas have accounted for more than half of the global total nitrogen from biological fixation since the 2000s.**
- → **Asia contributed about 40 percent to the global surplus over the entire period and across all nutrients.**
- → **High levels of nitrogen, phosphorus and potassium use efficiencies in Africa indicate soil nutrient mining in many parts of the region.**
- → **In Europe, a large proportion of total nutrient inputs come from manure applied to soils.**
- → **Oceania had a small contribution to the world total, accounting for only 1–2 percent of total inputs and outputs for all nutrients over the whole period.**

# FAOSTAT CROPLAND NUTRIENT BALANCE

## BACKGROUND

Cropland nutrient balances are an important indicator of nutrient flows that can signal an excess or insufficiency on cropland. The three main nutrients for plant growth are nitrogen (N), phosphorus (P), and potassium (K). Excess nutrient loads on cropland represent environmental risks such as nitrate leaching, erosion or runoff into water bodies and ammonia volatilization ($NH_3$) or emissions of nitrous oxide ($N_2O$) and nitrogen oxides ($NO_x$). Nutrient deficits indicate soil nutrient mining, which may also result in lower crop yield. Differences in trends and levels for phosphorus and potassium give indications where alternative pathways for sustainable nutrient management, such as changes in the composition of synthetic fertilizers, may be better strategies. For example, when there is a high deficiency in phosphorus, more of this nutrient may be added to the nutrient of a mineral fertilizer composite.

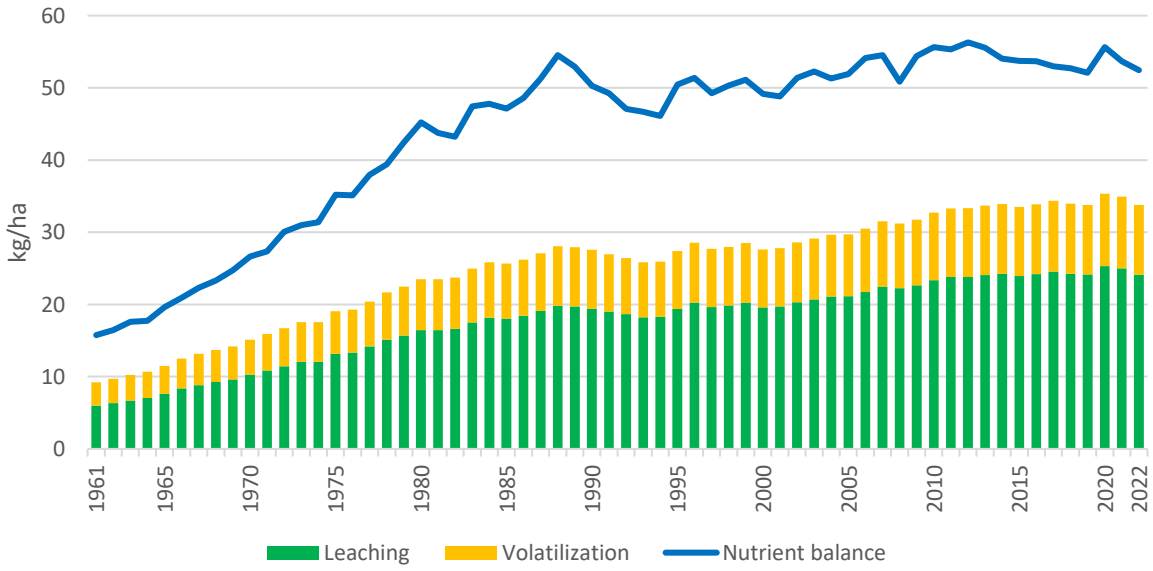
The key inputs of nutrients are *synthetic and mined fertilizers* (sometimes also referred to as mineral fertilizers, *manure applied to soils*, *biological fixation*, and *atmospheric deposition* (both reduced and oxidized compounds) and *seed*. The output from cropland is in the form of *crop removal* from harvest. The difference between these inputs and outputs is the *nutrient balance (*McLellan *et al.*, 2018). The cropland nutrient balance, as presented here, does not account for the heterogeneity of baseline soil nutrient properties across countries nor nutrient retention/mining across successive periods; the indicator also does not account for nutrients in inputs and outputs of crop residues or losses in the form of gaseous emissions and leaching, erosion or runoff into water bodies. Nonetheless, trends over time of the nutrient balance give an important indication of how efficiently agricultural inputs are being applied

with respect to outputs as well as an indicator of pollution risk and potential nutrient deficiency. In addition, nitrogen losses through volatilization (in the form of ammonia, nitrous oxide and $NO_x$) and leaching (in the form of nitrate and dissolved organic nitrogen) are also disseminated for illustrative purposes, to give the reader a better understanding of their relative importance within the overall balance. For phosphorus and potassium, losses do not occur in the form of volatilization, and there are no data for leaching for these nutrients in the FAOSTAT database. Figure 1 shows that leaching and volatilization would account for losses of 37 million tonnes (Mt), or 25 kg per hectare (ha) of cropland (58 percent) on average for the whole period. Furthermore, while the nitrogen balance has increased by 15 percent in the most recent decade compared to the 1990s, including these loss components leads to a slight reduction by 6 percent over the same period. The results analysed in this brief for the nutrient surplus, without accounting for leaching/volatilization, give a better indication of environmental risks.

Alternative normalizations and indices have been published. These include the Sustainable Nitrogen Management Index (SNMI), which combines nitrogen use efficiency and land use productivity to assess the environmental impact of agricultural production (Zhang *et al.*, 2022). Fertilizer dependency is an indicator for assessing the reliance on applied nitrogen fertilizers (organic or mineral) in a country compared to total inputs (including biological nitrogen fixation and deposition). It can give an indication both on the vulnerability of a country to market fluctuations in this agricultural input as well as on the sustainability of the agricultural practices in the country (Quemada and Lassaletta, 2024).

In this brief, nutrient balances are presented both as total nutrient flows and per area of cropland. The definition of cropland corresponds to that of FAOSTAT (land used for cultivation of crops, equal to the total of areas under arable land and permanent crops). Global and regional trends are analysed along with highlights of the most important contributors to the overall balance and how these main contributors have changed over time. Country results are presented for the cropland nutrient balance total.

**Figure 1: Global nitrogen balance, leaching and volatilization per cropland area**

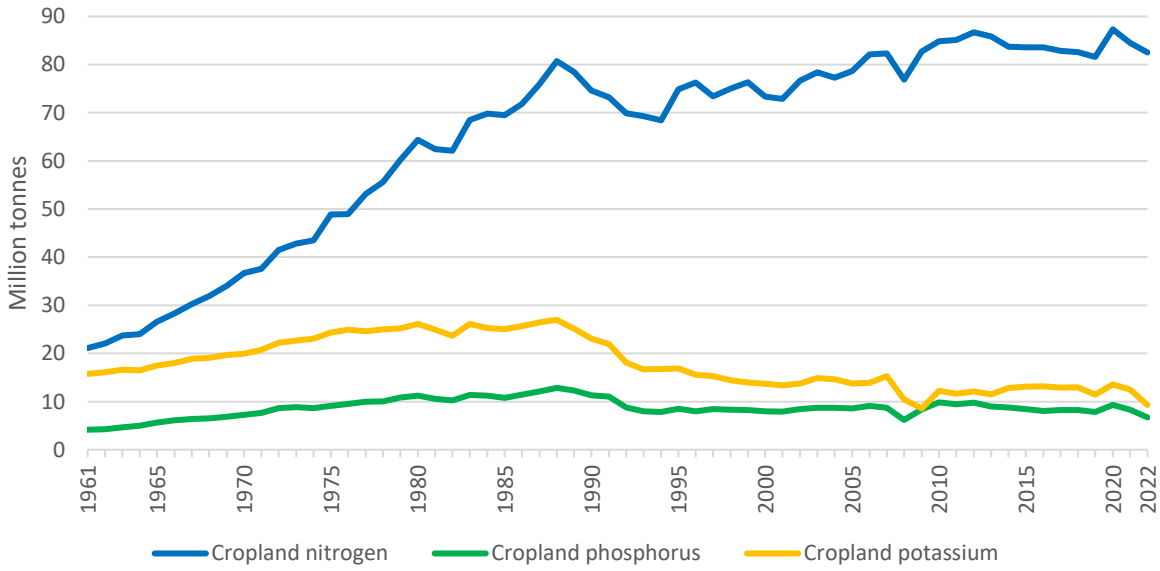



**Source:** FAO. 2024. FAOSTAT: Cropland nutrient balance. [Accessed November 2024]. https://www.fao.org/faostat/en/#data/ESB. Licence: CC-BY-4.0.

## GLOBAL

At the global level, the cropland nutrient surplus in 2022 was 83 Mt of N, 7 Mt of P and 9 Mt of K distributed over cropland at average surpluses of 52 kg N per ha (compared to a maximum N surplus of 80 kg per ha per year [EU Nitrogen Expert Panel, 2015]), 4 kg P per ha, and 6 kg K per ha. Researchers such as Rockström *et al.* (2023) define a global nitrogen boundary after accounting for harm from groundwater nitrate at 57 (with a lower safe bound of 34 and an upper safe bound of 74) Mt of N per year. Figure 2 shows that there was a substantial, 3.1-fold increase in the total cropland nitrogen balance in the most recent decade compared with the 1960s, while the phosphorus cropland balance remained nearly constant since the 1990s and the potassium balance declined by 29 percent over the same period. The differences in the trends for the three nutrient balances may be the result of a more focused attention on nitrogen as the limiting nutrient for crop production compared to phosphorus and potassium. The increases for nitrogen can mainly be attributed to a growth in the use of mineral fertilizers, which multiplied by 5.9 from 17 Mt in the 1960s to 101 Mt in the last ten years, and a substantially lower increase in crop removal (with a 3.3-fold increase from 29 Mt in the 1960s to 98 Mt over the least ten years). For phosphorus, a 3.1-fold increase in mineral fertilizers use offset a similar increase in crop removal (from 6 Mt to 18 Mt over the same period). The reduction in the potassium cropland balance is due to a larger increase in crop removal (from 13 Mt to 42 Mt) compared to that of mineral fertilizers (from 9 Mt to 29 Mt).

**Figure 2: Global cropland nutrient balance by nutrient**



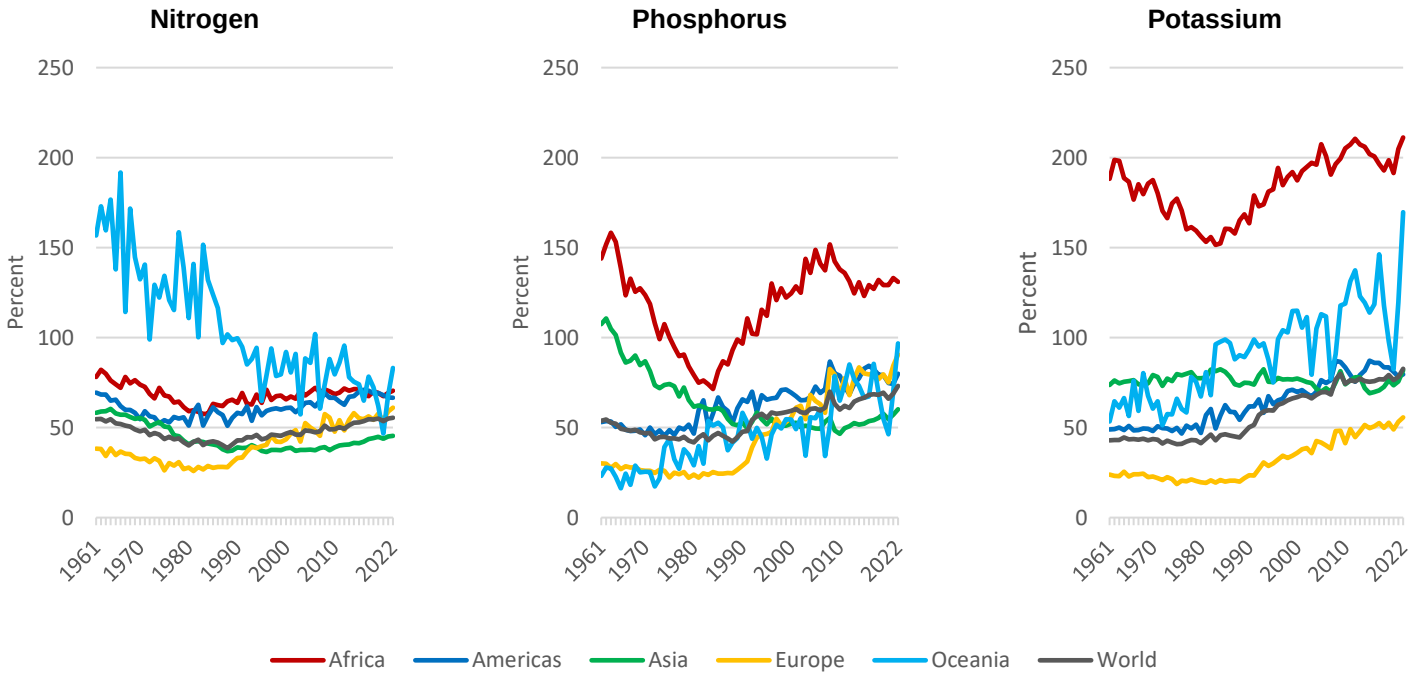

**Source:** FAO. 2024. FAOSTAT: Cropland nutrient balance. [Accessed November 2024]. https://www.fao.org/faostat/en/#data/ESB. Licence: CC-BY-4.0.

Nutrient use efficiency, calculated as the ratio of nutrient removal from crops to total nutrient input, is a measure of how well crops use available nutrients. High values of nitrogen use efficiency (greater than 90 percent) indicate risks of nutrient mining of soils, while low values (less than 50 percent) indicate risks of nutrient misuse and pollution (EU Nitrogen Expert Panel, 2015). Nitrogen use efficiency declined between the 1960s (53 percent) and the 1980s (41 percent). Since then, although not surpassing the value of the 1960s, nitrogen use efficiency has increased to 54 percent in the most recent decade.

Declining values of nutrient use efficiency indicate the use of more inputs compared to outputs. At the global scale, less targeted approaches for nutrient applications played a role for the decline up until the 1990s. Afterwards, more effective application of inputs and progresses made in agricultural machinery and technology contributed to the increase in nitrogen efficiency. Phosphorus use efficiency has followed a similar trajectory with values of 51 percent in the 1960s and 44 percent in the 1980s, but the efficiency in the most recent decade is at an all-time high of 68 percent. Lastly, potassium use efficiency remained stable until 1990, with values of 43 percent in the 1960s and 45 percent in the 1980s before increasing to 59 percent in the 1990s and reaching a record high 77 percent in the most recent decade. The average nutrient use efficiency over the whole period for the world was 48 percent for nitrogen, 54 percent for phosphorus, and 57 percent for potassium (Figure 3), which is below the 2022 levels for all nutrients (55 percent, 73 percent and 83 percent, respectively).

The relative importance of the different inputs contributing to the global total cropland nutrient surplus has also changed since the 1960s. For all three nutrients, mineral fertilizers use has taken an ever increasingly important role. The share of mineral fertilizers in total inputs increased from 31 percent in the 1960s to 56 percent in the most recent decade for nitrogen; during the same period it increased from 56 percent to 74 percent for phosphorus, and from 28 percent to 53 percent for potassium. In contrast to the other two nutrients, the most important input for potassium is manure applied to soils – while manure made up an average of 18 percent of total inputs over the entire period for nitrogen and 29 percent for phosphorus, it contributed to an average of 55 percent of total inputs for potassium.

**Figure 3: Nutrient use efficiency by region**




**Source:** FAO. 2024. FAOSTAT: Cropland nutrient balance. [Accessed November 2024]. https://www.fao.org/faostat/en/#data/ESB. Licence: CC-BY-4.0.

## REGIONAL

Over the whole period, **Africa** was above the world average for nitrogen use efficiency (68 percent) and had the highest phosphorus and potassium use efficiencies (118 percent and 184 percent, respectively), indicating that cropland in the region is running a deficit for these two nutrients. The nutrient use efficiencies for the region in 2022 were 71 percent for N, 131 percent for P, and 211 percent for K. The **Americas** were above the world average, although closer than most of the regions, for cropland nutrient use efficiencies (61 percent for N, 63 percent for P, and 64 percent for K). The nutrient use efficiencies for the Americas in 2022 were 67 percent for N, 80 percent for P, and 80 percent for K. **Asia** used nitrogen with almost the same efficiency as the world (44 percent) but more efficiently for phosphorus (63 percent) and potassium (76 percent). The nutrient use efficiencies for Asia in 2022 were 45 percent for N, 60 percent for P, and 82 percent for K. The nutrient efficiency in **Europe** was slightly below the global average, although the efficiency for nitrogen and phosphorus use had in recent decades been very close to the world average. The nutrient use efficiencies for Europe in 2022 were 61 percent for N, 91 percent for P, and 56 percent for K. Trends in Europe and in turn for the world can partially be explained by the introduction in 1991 of the European Union (EU) Nitrates Directive to reduce water pollution caused by leaching and runoff as well as the collapse of the Soviet Union. In **Oceania**, nitrogen use efficiency began high in the 1960s (158 percent) but steadily declined to 70 percent in the most recent decade, whereas phosphorus use efficiency steadily rose and was near the world average in the most recent decade at 71 percent. Potassium use efficiency (92 percent over the whole period) remained above the world average. The nutrient use efficiencies for Oceania in 2022 were 83 percent for N, 97 percent for P, and 170 percent for K.

Figures 4 to 7 show that the trends and levels of the cropland nutrient surplus per hectare of cropland differed significantly by region between 1961 and 2022.

Until the 1980s, nitrogen deposition along with biological nitrogen fixation accounted for more than half of total nitrogen inputs in **Africa**. Over the whole period, the region has a low nitrogen surplus per ha of cropland (8 kg N per ha), and a nutrient deficit per ha of cropland for phosphorus (−0.5 kg P per ha) and potassium (−5 kg K per ha). This indicates decades of soil nutrient mining in many parts of the region, also reflected by the high levels of nitrogen, phosphorus and potassium use efficiencies. The share of fertilizer to total inputs rose until the 1990s (from 20 percent in the 1960s to 41 percent in the 1980s for N, from 58 percent to 74 percent for P, and from 23 percent to 36 percent for K) after which it began to decline (reaching 38 percent for N, 65 percent for P and 33 percent for K in the most recent decade). The cropland nutrient balance for the region in 2022 was 11 kg per ha for N, −1 kg per ha for P, and −7 kg per ha for K.

The **Americas** have accounted for more than half of the global total nitrogen from biological fixation since the 2000s, and in the most recent decade, nitrogen inputs from biological fixation (22 Mt on average per year) exceeded mineral fertilizer N (21 Mt), mainly due to large areas of soybean cropping. The region is near the world average for nutrient surpluses per ha of cropland (32 kg N per ha, 5 kg P per ha, and 10 kg K per ha). Over the whole period, manure accounted for 14 percent of total inputs for N, 26 percent for P, and 43 percent for K. The cropland nutrient balance for the region in 2022 was 48 kg per ha for N, 4 kg per ha for P, and 9 kg per ha for K.

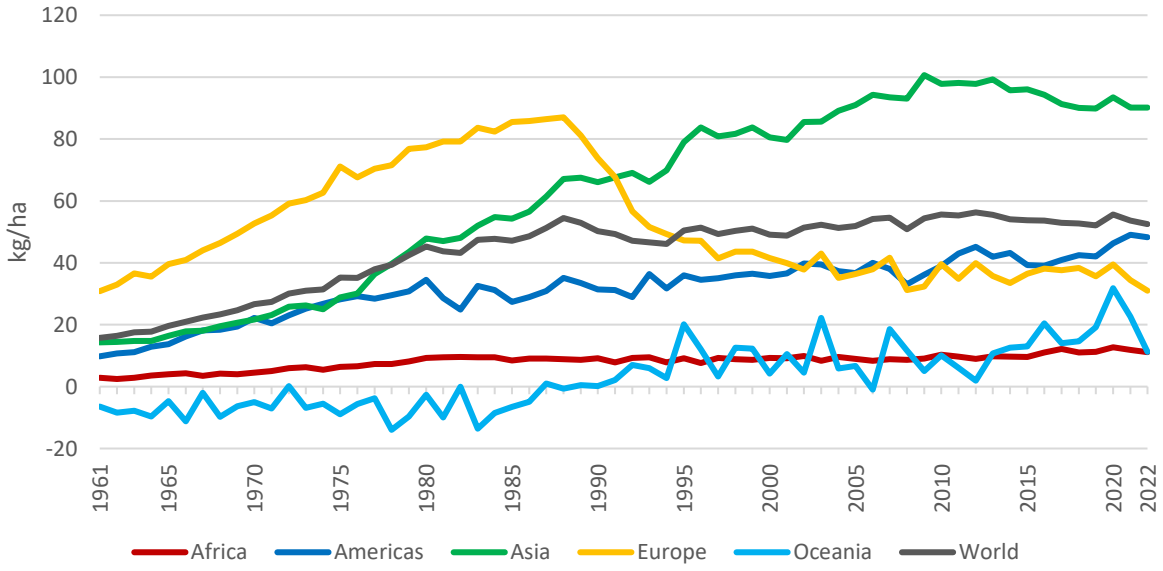
**Asia** was the biggest contributor of total nutrient inputs to the global total in the most recent decade, accounting for approximately half of total nutrients applied for N (52 percent), P (55 percent) and K (48 percent). Although the region has the highest nitrogen surplus per unit area as of the 1990s (75 kg N per ha of cropland in that decade) and phosphorus balance per unit area as of the 2000s (10 kg P per

ha of cropland in that decade), this is not true for the potassium balance per unit area, which averaged 7 kg K per ha of cropland over the whole period. As of the 2000s, the region became the largest contributor to manure nutrients applied to soils, contributing to more than 40 percent of the world total for all three nutrients. In the most recent decade, Asia was responsible for more than half of global nutrient inputs from mineral fertilizers (60 percent for N, 58 percent for P, and 51 percent for K). The cropland nutrient balance for the region in 2022 was 90 kg per ha for N, 9 kg per ha for P, and 8 kg per ha for K. Although Asia only contributed 2 percent to the global phosphorous surplus and 9 percent to the global potassium surplus in the 1960s, the region contributed about 40 percent to the global surplus over the entire time period and across all nutrients.

For **Europe**, a large proportion of total nutrient inputs come from manure applied to soils, averaging 32 percent for N, 40 percent for P, and 62 percent for K over the whole period. The region saw a dramatic drop between the 1980s and the 1990s in the cropland nutrient surplus for the three nutrients: −39 percent for N, −56 percent for P and −42 percent for K. Although the region moved below the world average for the cropland nitrogen and phosphorus balances per unit area in the 2000s (38 kg N per ha and 4 kg P per ha), it has remained above the world average for the cropland potassium balance per unit area over the entire period (averaging 37 kg K per ha per year between 1961 and 2022, as shown in Figure 6). The cropland nutrient balance for the region in 2022 was 31 kg per ha for N, 1 kg per ha for P, and 14 kg per ha for K.

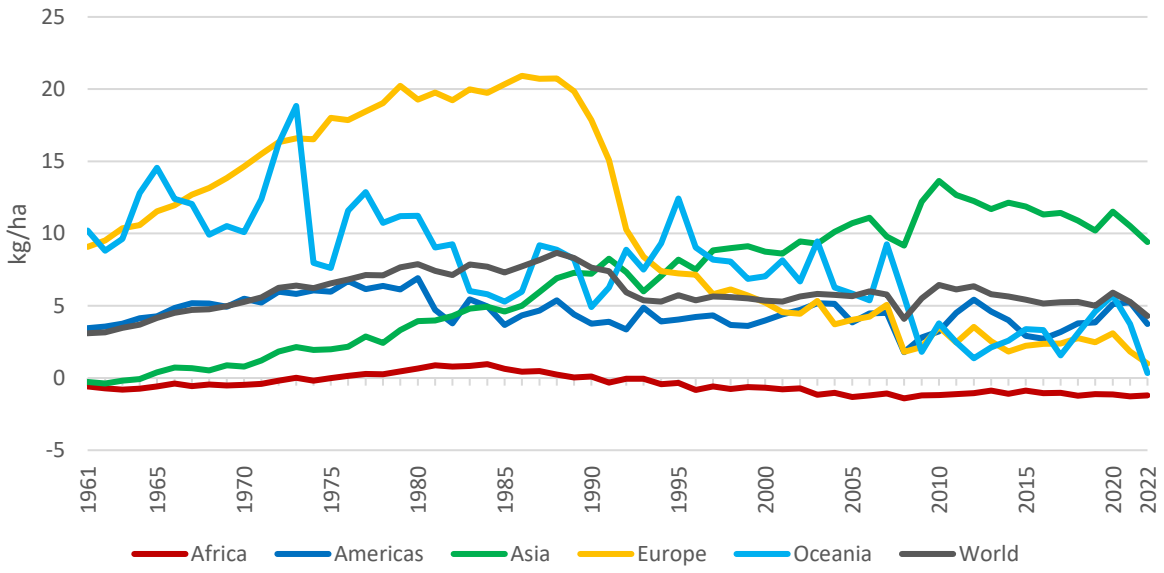
**Oceania** had a small contribution to the world total, accounting for only 1–2 percent of total inputs and outputs for all nutrients over the whole period. For nitrogen, share of mineral fertilizers in total inputs increased from 33 percent in the 1960s to 44 percent in the 1970s and overtook the share of manure applied to soils, which reduced from 40 percent to 35 percent. The contributions of manure applied to soils remained low for phosphorus (averaging 12 percent over the whole period) but was high for potassium (averaging 58 percent over the whole period). The cropland nutrient balance for the region in 2022 was 11 kg per ha for N, 0.3 kg per ha for P, and −8 kg per ha for K.

**Figure 4: Cropland nitrogen balance per cropland area by region**



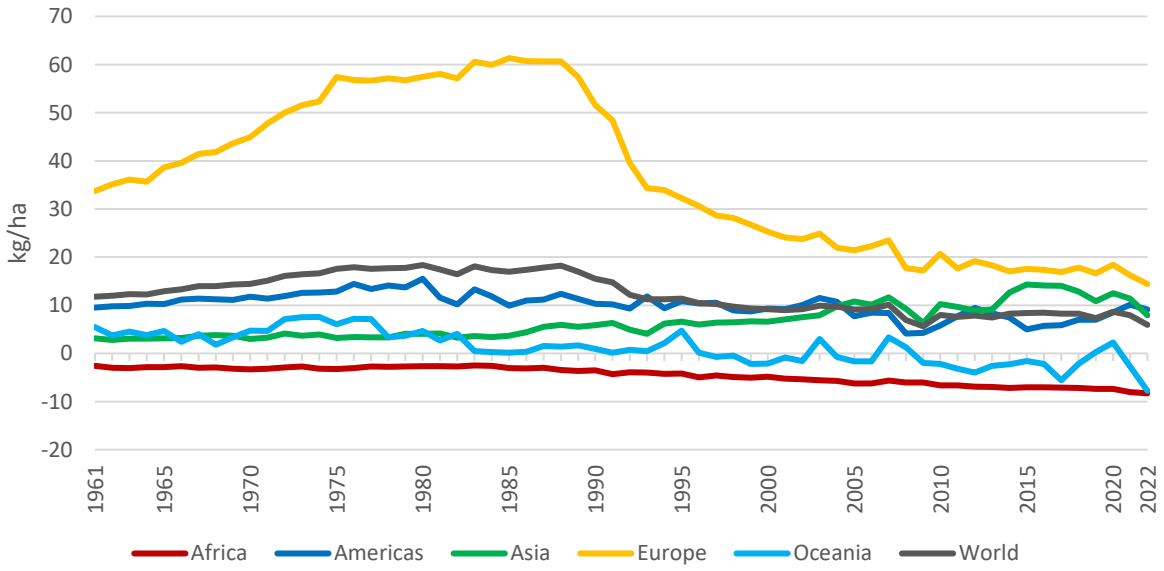

**Source:** FAO. 2024. FAOSTAT: Cropland nutrient balance. [Accessed November 2024]. https://www.fao.org/faostat/en/#data/ESB. Licence: CC-BY-4.0.

**Figure 5: Cropland phosphorus balance per cropland area by region**



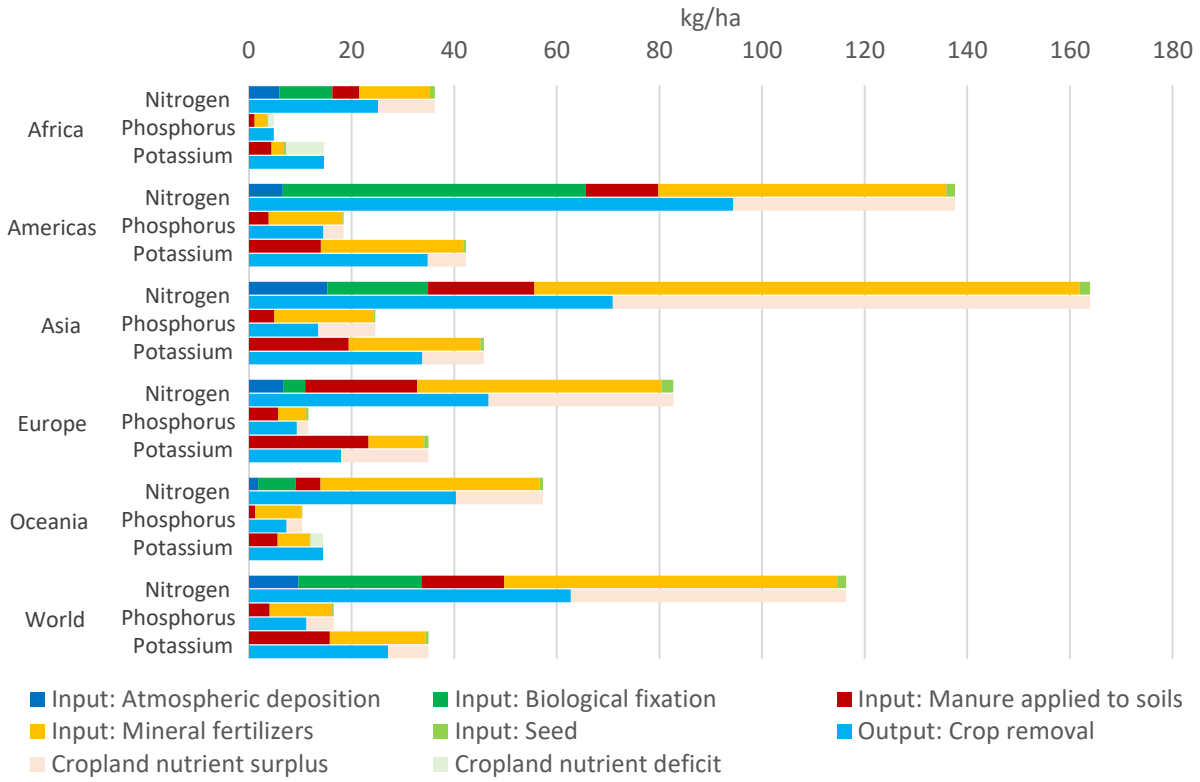

**Source:** FAO. 2024. FAOSTAT: Cropland nutrient balance. [Accessed November 2024]. https://www.fao.org/faostat/en/#data/ESB. Licence: CC-BY-4.0.

**Figure 6: Cropland potassium balance per cropland area by region**




**Source:** FAO. 2024. FAOSTAT: Cropland nutrient balance. [Accessed November 2024]. https://www.fao.org/faostat/en/#data/ESB. Licence: CC-BY-4.0.

**Figure 7: Cropland nutrient balances by region and nutrient, 2013–2022 average**



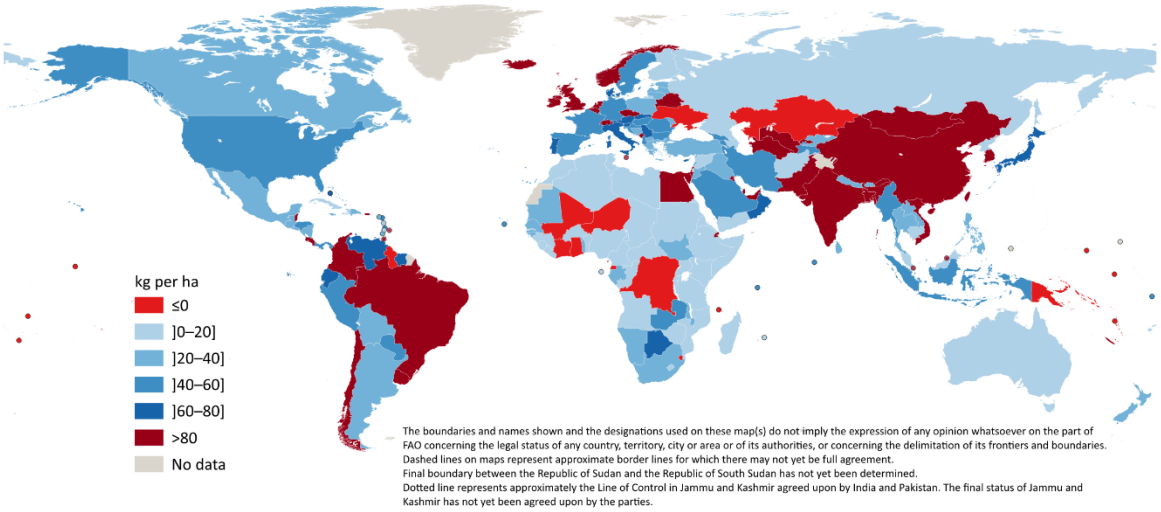

**Source:** FAO. 2024. FAOSTAT: Cropland nutrient balance. [Accessed November 2024]. https://www.fao.org/faostat/en/#data/ESB. Licence: CC-BY-4.0.

## COUNTRY

Figures 8 and 9 show the large heterogeneity in the cropland nitrogen balance per area of cropland and use efficiency among countries in 2022. The thresholds for these maps were derived from the 2015 EU Nitrogen Expert Panel, which specified that the desired maximum N surplus is less than 80 kg/ha and the desired nitrogen use efficiency is between 50 percent and 90 percent. Most countries in Africa have cropland nitrogen balance values of 0–40 kg per ha, while most European countries have a cropland nitrogen surplus of 40–80 kg/ha. As suggested by Figure 5, some of the highest values are found in Asia.

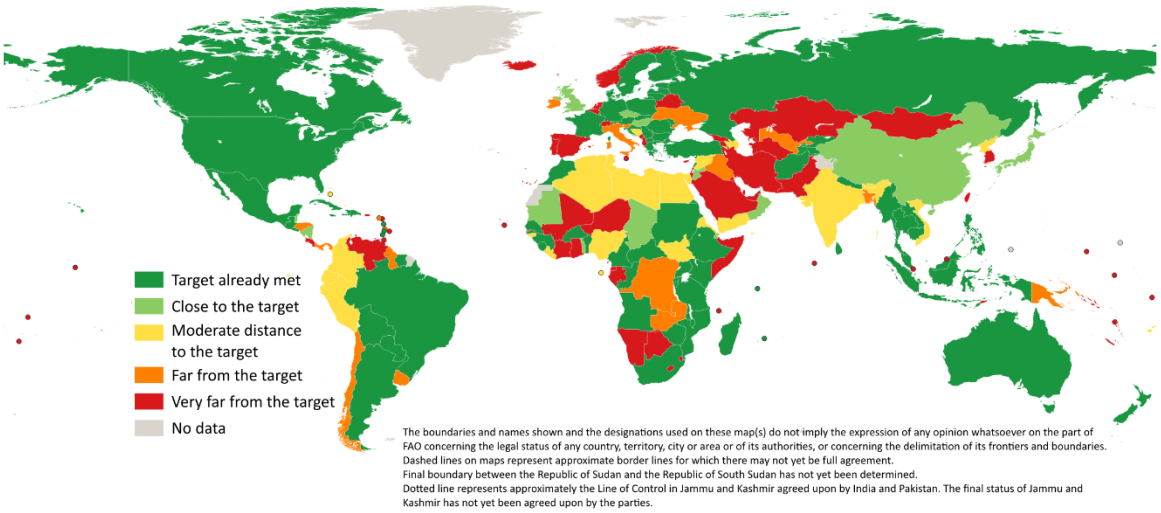
Combining Figures 8 and 9, some countries show differences between their status for the nitrogen balance versus their nitrogen use efficiency. For example, while Brazil is on the upper end of the cropland nitrogen balance, the country has a nitrogen use efficiency within the desired range, indicating that the soybean practices in the country may effectively increase the outputs relative to the inputs. On the other hand, other countries such as Namibia (displaying moderate levels of cropland nitrogen balance but low levels of nitrogen use efficiency) may still be at risk of nutrient depletion. The nitrogen use efficiency captures the efficiency of outputs in terms of the levels of inputs applied, regardless of the order of magnitude. As a result, countries with very low levels of output relative to low levels of inputs (for example in sub-Saharan Africa) can have efficiencies similar to those of countries with high levels of output relative to very high levels of inputs (such as China and India).

**Figure 8: Cropland nitrogen balance per cropland area, 2022**




**Source:** FAO. 2024. FAOSTAT: Cropland nutrient balance. [Accessed November 2024]. https://www.fao.org/faostat/en/#data/ESB. Licence: CC-BY-4.0.

**Figure 9: Cropland nitrogen use efficiency, 2022**



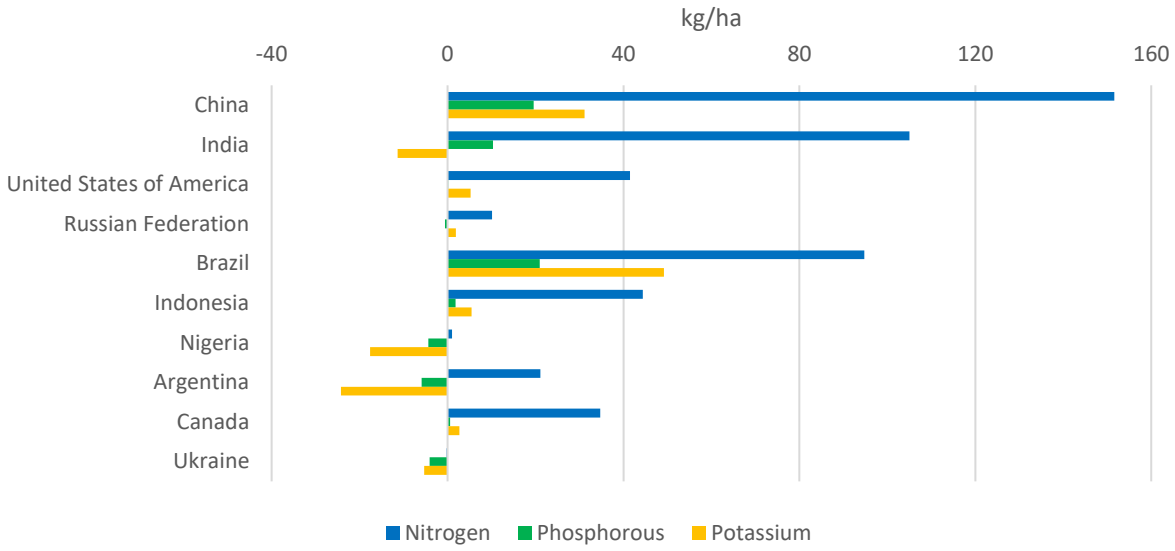

**Note:** The bounds correspond to those of the proxy measure of the subindicator theme “soil quality” under the environment dimension of Sustainable Development Goal Indicator 2.4.1 (proportion of agricultural area under productive and sustainable agriculture).

**Source:** FAO. 2024. FAOSTAT: Cropland nutrient balance. [Accessed November 2024]. https://www.fao.org/faostat/en/#data/ESB. Licence: CC-BY-4.0.

The countries with the largest cropland area show different profiles of the cropland nutrient balances by nutrient for 2022, as shown on Figure 10. Of these countries, China, India and Brazil all have nitrogen balances higher than the global average, while the United States of America, the Russian Federation, Indonesia, Nigeria, Argentina, Canada and Ukraine all have nitrogen balances lower than the global average. China, the United States of America, Brazil, Indonesia and Canada have surpluses for all three

nutrients, while India and the Russian Federation have surpluses for two nutrients (including nitrogen in all cases) and a small deficit in another. Argentina and Nigeria have a surplus for nitrogen and deficits in the other two nutrients. Ukraine has a deficit in all three nutrients, possibly because of the increased price of fertilizers due to the war in the country.

**Figure 10: Cropland nutrient balance per cropland area by nutrient, selected countries, 2022**




**Note:** Countries are listed in descending order of cropland area, from China (first) to Ukraine (tenth).

**Source:** FAO. 2024. FAOSTAT: Cropland nutrient balance. [Accessed November 2024]. https://www.fao.org/faostat/en/#data/ESB. Licence: CC-BY-4.0.

## EXPLANATORY NOTES

- The 2024 update of the cropland nutrient balance is a joint effort of FAO with the International Fertilizer Association (IFA) in collaboration with the University of Maryland Center for Environmental Science, the Swedish University of Agricultural Sciences, CEIGRAM-Universidad Politécnica de Madrid, Wageningen University & Research, the University of Nebraska and the African Plant Nutrition Institute. The group contributed to the overall quality of the data and text within the analytical brief. The FAOSTAT domain Cropland nutrient balance disseminates nutrient flows in a given country and year. The cropland nutrient balance can give an indication of nutrient use efficiency, as it can help quantify excess nutrients leading to environmental risks, for instance, greenhouse gas emissions or pollution from volatilization and leaching/runoff. It can also signal cropland nutrient deficits that limit crop production.
- The nutrient balance (NB) is calculated as the sum of inputs: mineral fertilizers (MF) multiplied by the fraction of fertilizer applied to cropland (CF), manure applied to soils (MAS), nitrogen deposition (ND), and biological fixation (BF), seed (SD) minus outputs: crop removal (CR).
- The definition of cropland corresponds to that of FAOSTAT.
- Data for mineral fertilizers are sourced from the Fertilizers by Nutrient FAOSTAT domain for the element “Agricultural Use” and the items “Nutrient nitrogen N (total)”, “Nutrient phosphate P2O5 (total)”, and “Nutrient potash K2O (total)”.
- IFA data for mineral fertilizers are sourced from the IFA consumption database: https://www.ifastat.org/databases/plant-nutrition.

  For records with data for both FAO and IFA, the average of the two data sources was used.
- Data for chemical compounds are converted to the elements P and K using the mass percent composition conversions of 0.436 for P and 0.830 for K.
- A full description of all the data sources for the domain is available here.

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