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FAOSTAT ANALYTICAL BRIEF 52

Cropland nutrient budget

Global, regional and country trends, 1961–2020

>> FAO Statistics Division

HIGHLIGHTS

- **The 2022 update of the cropland nutrient budget is a joint effort of the Food and Agriculture Organization of the United Nations (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 data help quantify nutrient surpluses (leading to environmental risks) or deficits (which may limit crop yield) on cropland.**
- **At the global level, the cropland nutrient surplus in 2020 was at an all-time high of 85 million tonnes (Mt) of nitrogen (N), 7 Mt of phosphorus (P), and 12 Mt of potassium (K) corresponding to average surpluses of 54 kg N per ha, 4 kg P per ha, and 7 kg K per ha.**
- **The average global nutrient use efficiency over the 1961–2020 period was 50 percent for N, 62 percent for P, and 59 percent for K.**
- **Asia was the biggest contributor of total nutrients inputs to the global total in the most recent decade, accounting for approximately half of total nutrients applied for N (53 percent), P (55 percent) and K (49 percent).**

FAOSTAT CROPLAND NUTRIENT BUDGET

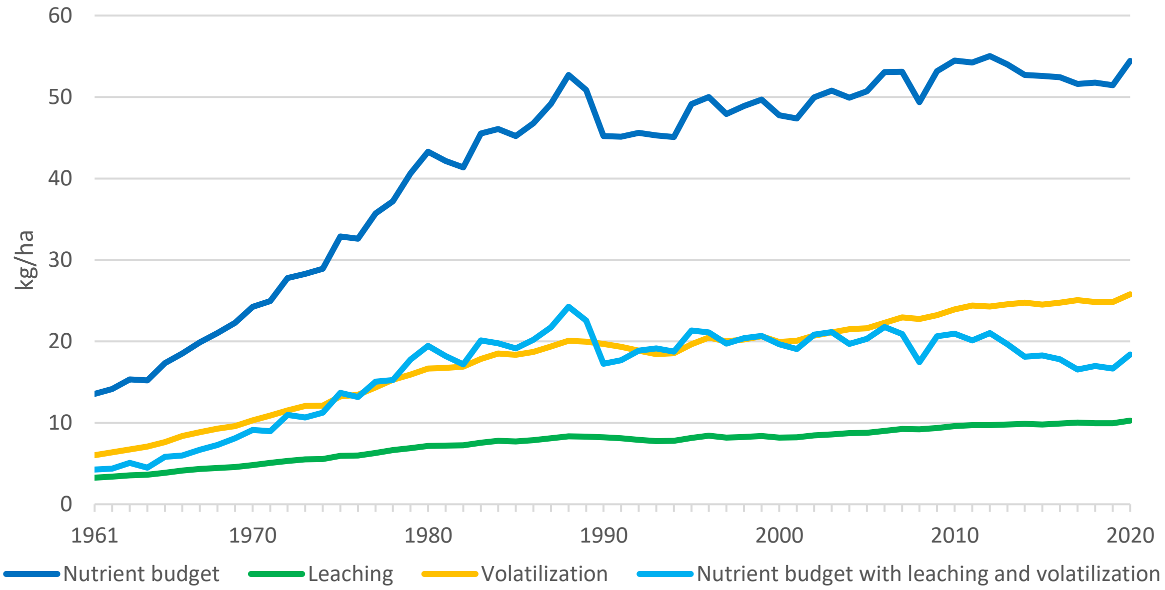
BACKGROUND

Cropland nutrient budgets 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 and NO_x. Nutrient deficits indicate soil nutrient mining, which may also result in lower crop yield. While the data published in 2021 covered only nitrogen (to which much priority has been given as both a stimulant and pollutant in nutrient management programmes), new to the 2022 update is that all three main nutrients are included in the analysis. Differences in trends and levels for phosphorous 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 phosphorous, more of this nutrient may be added to the nutrient of a mineral fertilizer composite. The nutrient budgets presented here should interpreted also taking under consideration the global yield gap atlas.

The key inputs of nutrients are *synthetic fertilizers* (also referred to as "mineral" fertilizers for phosphorous and potassium), *manure applied to soils*, *biological fixation*, and *atmospheric deposition (both reduced and oxidized compounds)*. The output from cropland is in the form of *crop removal* from harvest. The difference between these inputs and outputs is the *nutrient budget*. The 2022 update of the domain resulted in a reduction of 12 percent for the entire period and of 15 percent from the 1990s onwards. Over the entire period, there was a 9 percent reduction for atmospheric deposition, a 40 percent increase for biological nitrogen fixation, a 15 percent increase for crop removal, a 7 percent reduction in manure applied to soils, and a 12 percent reduction for synthetic fertilizer. The cropland nutrient budget, 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 budget 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 NOx) and leaching (in the form of nitrates) are also disseminated for illustrative purposes, to give the reader a better understanding of their relative importance within the overall budget. For phosphorous 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 incorporating leaching and volatilization as losses in the nitrogen budget results in a reduction by 37 million tonnes, or 25 kg per hectare (ha) of cropland (61 percent) on average for the whole period. Furthermore, while the nitrogen surplus has increased by 17 percent in the most recent decade compared to the 1990s, including these loss components leads to a slight reduction by 2 percent over the same period. The results analysed in this brief for the nutrient surplus give a better indication of environmental risks.

In this brief, nutrient budgets are presented both as total nutrient flows and per area of cropland. Global and regional trends are analysed along with highlights of the most important contributors to the overall budget and how these main contributors have changed over time. Lastly, country results are presented for the cropland nutrient budget total.

Figure 1: Global nitrogen budget with and without leaching and volatilization

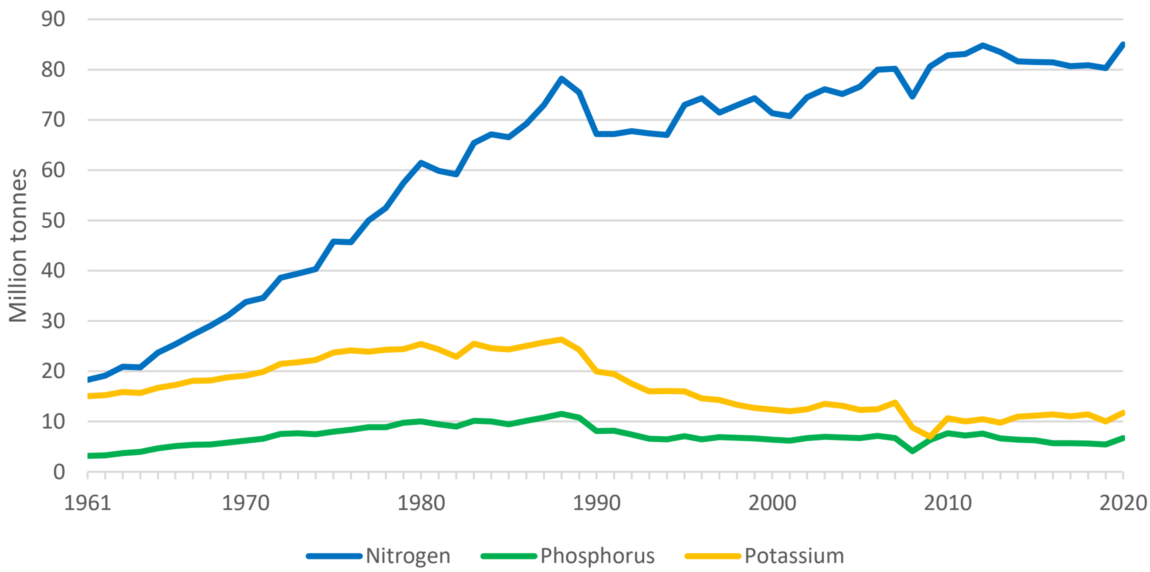


Source: FAO. 2022. FAOSTAT: Cropland nutrient budget. In: *FAO*. Rome. Cited November 2022. https://www.fao.org/faostat/en/#data/ESB

GLOBAL

At the global level, the cropland nutrient surplus in 2020 was 85 million tonnes (Mt) of N, 7 Mt of P, and 12 Mt of K distributed over cropland at rates of 54 kg N per ha (compared to a desired maximum N surplus of 80 kg per ha per year [EU Nitrogen Expert Panel, 2015]), 4 kg P per ha, and 7 kg K per ha. Figure 2 shows that there was a substantial, 3.4-fold increase in the total cropland nitrogen budget, compared with the 1960s, while the phosphorus cropland budget remained nearly neutral since the 1990s and the potassium budget declined by 36 percent over the same period. The differences in the trends for the three nutrient budgets may be the result of a more focused attention on nitrogen as the limiting nutrient for crop production compared to phosphorous and potassium. The increases for nitrogen can mainly be attributed to a growth in the use of synthetic fertilizers, which multiplied by 5.7 from 18 Mt in the 1960s to 102 Mt in the 2010s, and a substantially lower increase in crop removal (with a 3.1-fold increase from 31 Mt in the 1960s to 97 Mt in the 2010s). For phosphorus, a 3.0-fold increase in synthetic fertilizers use offset a similar increase in crop removal (from 6 Mt to 19 Mt). The reduction in the potassium cropland budget is due to a larger increase in crop removal (from 14 Mt to 43 Mt) compared to that of synthetic fertilizer (from 9 Mt to 29 Mt).

Figure 2: Global cropland nutrient budget by nutrient



Source: FAO. 2022. FAOSTAT: Cropland nutrient budget. In: *FAO*. Rome. Cited November 2022. https://www.fao.org/faostat/en/#data/ESB

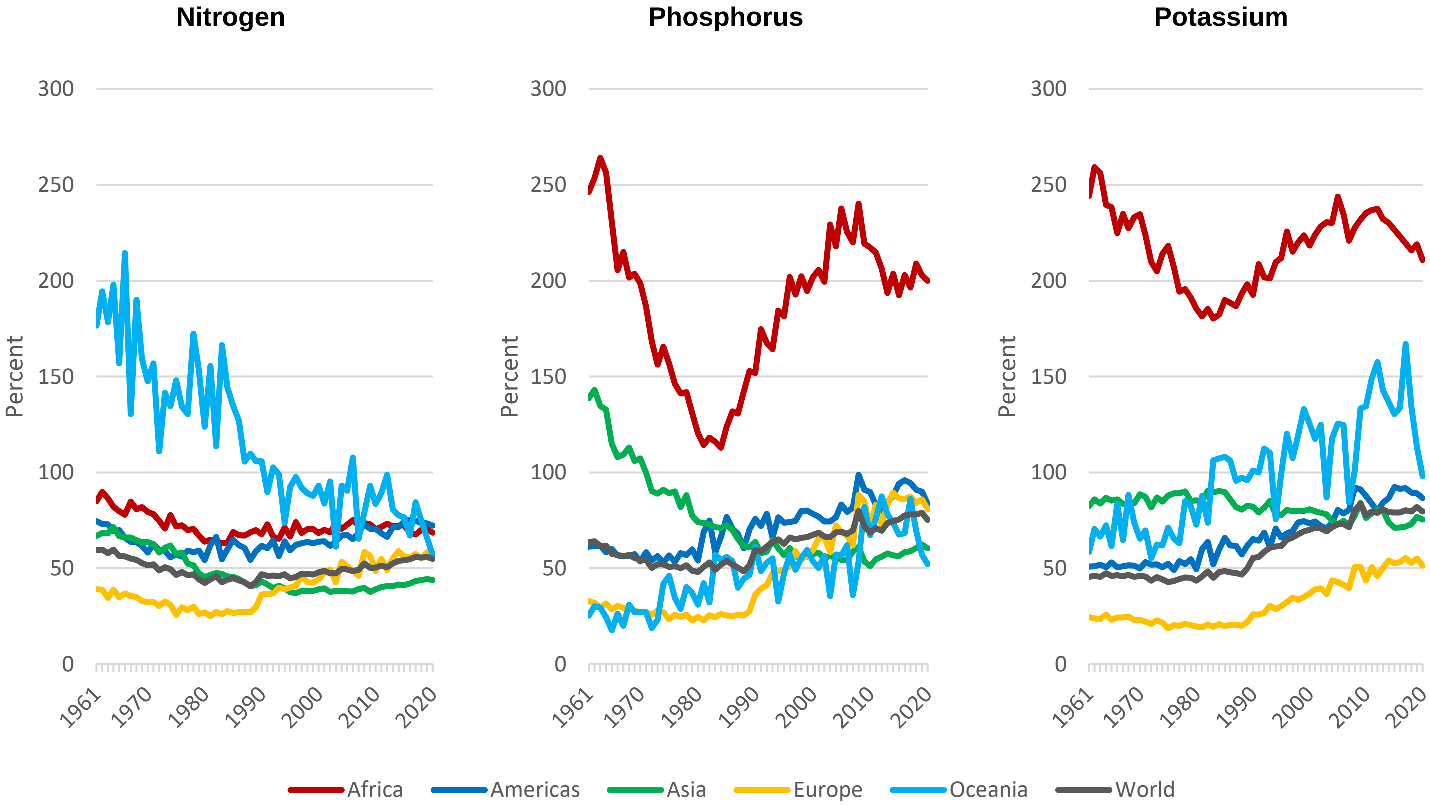
Nutrient use efficiency is a measure of how well crops use available nutrients; it is calculated as the ratio of nutrient removal from crops to total nutrient input. High values of nitrogen use efficiency (greater than 90 percent) indicate risks of nutrient mining of soils, while low values (less than 50 percent) indicate risks of insufficient nutrient use (EU Nitrogen Expert Panel, 2015). Nitrogen use efficiency declined between the 1960s (57 percent) and the 1980s (43 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; on a 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 59 percent in the 1960s and 51 percent in the 1980s, but the efficiency in the most recent decade is at an all-time high of 75 percent. Lastly, potassium use efficiency remained stable until 1990, with values of 46 percent in the 1960s and 47 percent in the 1980s before increasing to 62 percent in the 1990s and reaching an all-time high of 80 percent in the most recent decade. The average nutrient use efficiency over the whole period for the world was 50 percent for nitrogen, 62 percent for phosphorus, and 59 percent for potassium (Figure 3).

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, synthetic fertilizers use has taken an ever increasingly important role, making up for 32 percent of total inputs in the 1960s and 57 percent in the most recent decade for nitrogen, increasing from 59 percent to 75 percent for phosphorus, and from 29 percent to 45 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 21 percent of total inputs over the entire period for nitrogen and 31 percent for phosphorus, manure contributed to an average of 61 percent of total inputs for potassium.

REGIONAL

Over the whole period, **Africa** is above the world average for nitrogen use efficiency (72 percent) and has the highest phosphorus and potassium use efficiencies (186 percent and 217 percent, respectively), indicating that cropland in the region is running a deficit for these two nutrients. The **Americas** is above the world average, although closer than most of the regions, for cropland nutrient use efficiencies (65 percent for nitrogen, 72 percent for phosphorus, and 67 percent for potassium). **Asia** used nitrogen with almost the same efficiency as the world (48 percent) but more efficiently for phosphorus (75 percent) and potassium (82 percent). The nutrient efficiency in **Europe** is below the global average for nutrients, although the efficiency for nitrogen and phosphorus use has in recent decades been very close to the world average. In **Oceania**, nitrogen use efficiency began high in the 1960s (178 percent) but steadily declined to 77 percent in the most recent decade, whereas phosphorus use efficiency steadily rose and was near the world average in the most recent decade at 72 percent. Potassium use efficiency (100 percent over the whole period) remained above the world average (Figure 3).

Figure 3: Nutrient use efficiency by region



Source: FAO. 2022. FAOSTAT: Cropland nutrient budget. In: *FAO*. Rome. Cited November 2022. https://www.fao.org/faostat/en/#data/ESB

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 2020.

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 (7 kg N per ha), and a nutrient deficit per ha of cropland for phosphorus (-2 kg P per ha) and potassium (-5 kg K per ha). This indicates decades of soil nutrient mining in many parts of the region, as also reflected by the high levels of nitrogen, phosphorus and potassium use efficiencies. The contribution of synthetic fertilizers to the total budget for all three nutrients rose until the 1990s (from 21 percent in the 1960s to 42 percent in the 1980s for N, from 67 percent to 79 percent for P, and from 26 percent to 39 percent for K) after which it began to decline (reaching 39 percent for N, 68 percent for P, and 30 percent for K in the most recent decade).

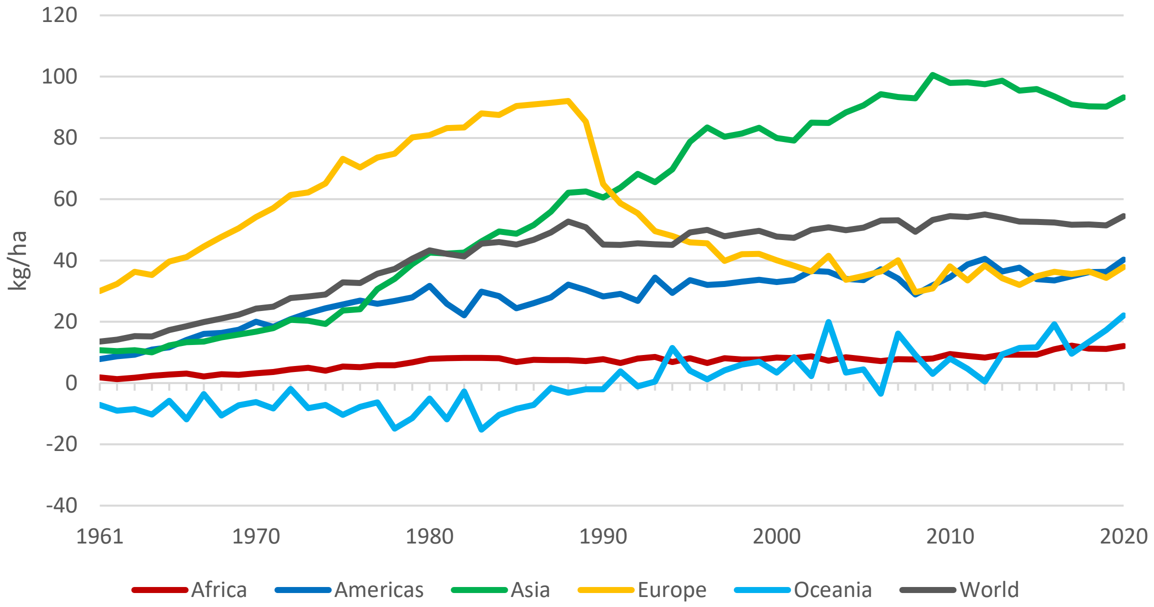
The **Americas** have accounted for more than half of the global total nitrogen from biological fixation since the 2000s, and in the most recent decade, nitrogen inputs from biological fixation (207 thousand tonnes [kt]) exceeded synthetic fertilizer N (202 kt), mainly due to large areas of soybean cropping. The region is near the world average for nutrient surpluses per ha of cropland (28 kg N per ha, 3 kg P per ha, and 9 kg K per ha). Over the whole period, manure accounted for 17 percent of total inputs for nitrogen, 28 percent for phosphorus, and 50 percent for potassium.

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 (53 percent), P (55 percent) and K (49 percent). Although the region has the highest nitrogen surplus per unit area as of the 1990s (74 kg N per ha of cropland) and phosphorus budget per unit area as of the 2000s (9 kg P per ha of cropland), the same is not true for the potassium budget per unit area, which averaged 5 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 synthetic fertilizers (62 percent for N, 59 percent for P, and 52 percent for K).

For **Europe**, a large proportion of total nutrient inputs come from manure applied to soils, averaging 34 percent for N, 44 percent for P, and 64 percent for K over the whole period. Following the introduction in 1991 of the European Union Nitrates Directive to reduce water pollution caused by leaching and runoff as well as the collapse of the Soviet Union, the region saw a dramatic drop between the 1980s and the 1990s in the cropland nutrient surplus for the three nutrients: -45 percent for N, -63 percent for P and -45 percent for K. Although the region moved below the world average for the cropland nitrogen and phosphorus budgets per unit area in the 2000s (36 kg N per ha and 3 kg P per ha), it has remained above the world average for the cropland potassium budget per unit area over the entire period (averaging 25 kg K per ha per year).

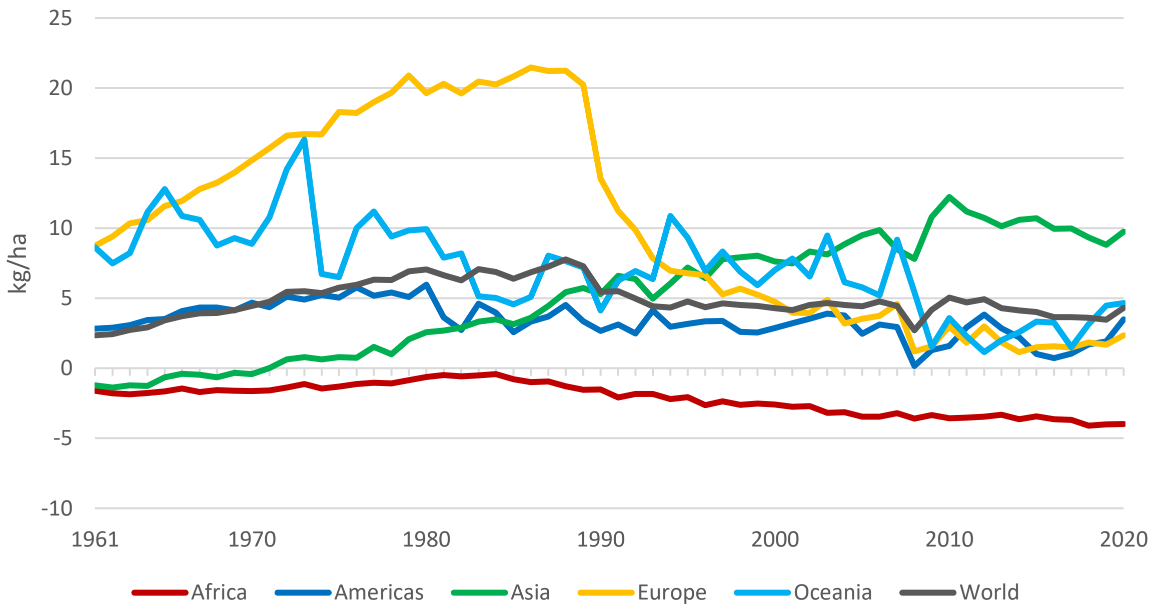
Oceania had a small contribution to the world total, accounting for only 1–4 percent of total inputs and outputs for all nutrients over the whole period. For nitrogen, from the 1960s to the 1970s, the contribution of synthetic fertilizers to total inputs increased from 35 percent to 46 percent to become greater than that of manure applied to soils, which reduced from 33 percent to 25 percent. The contributions of manure applied to soils for phosphorus remained low (averaging 12 percent over the whole period) whereas the contribution of manure applied to soils for K was high (averaging 61 percent over the whole period).

Figure 4: Cropland nitrogen budget per cropland area by region



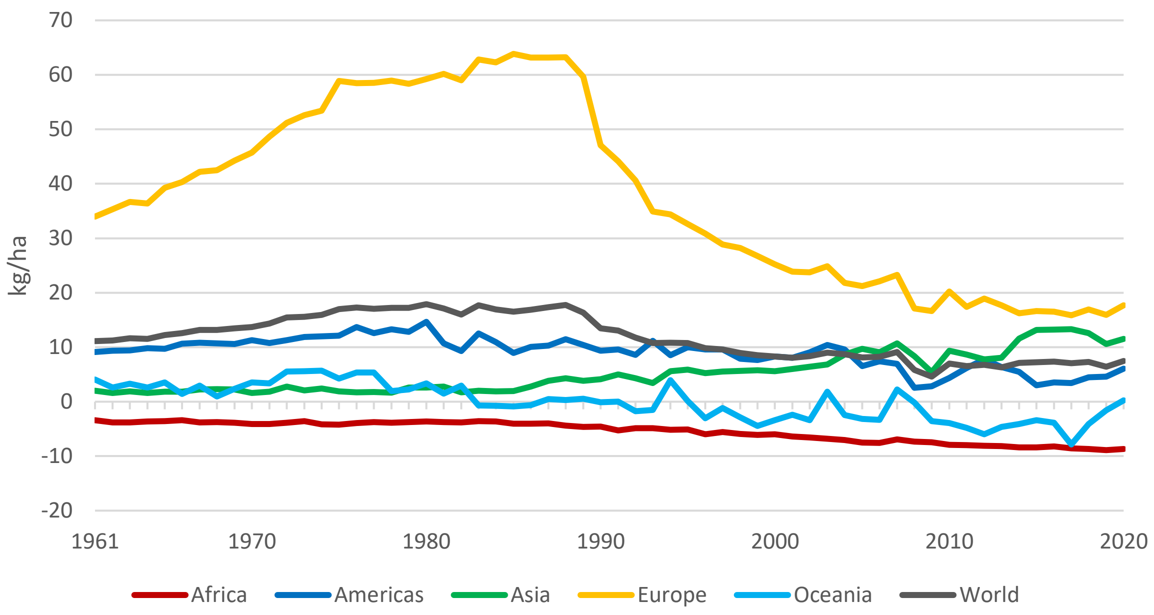
Source: FAO. 2022. FAOSTAT: Cropland nutrient budget. In: *FAO*. Rome. Cited November 2022. https://www.fao.org/faostat/en/#data/ESB

Figure 5: Cropland phosphorus budget per cropland area by region



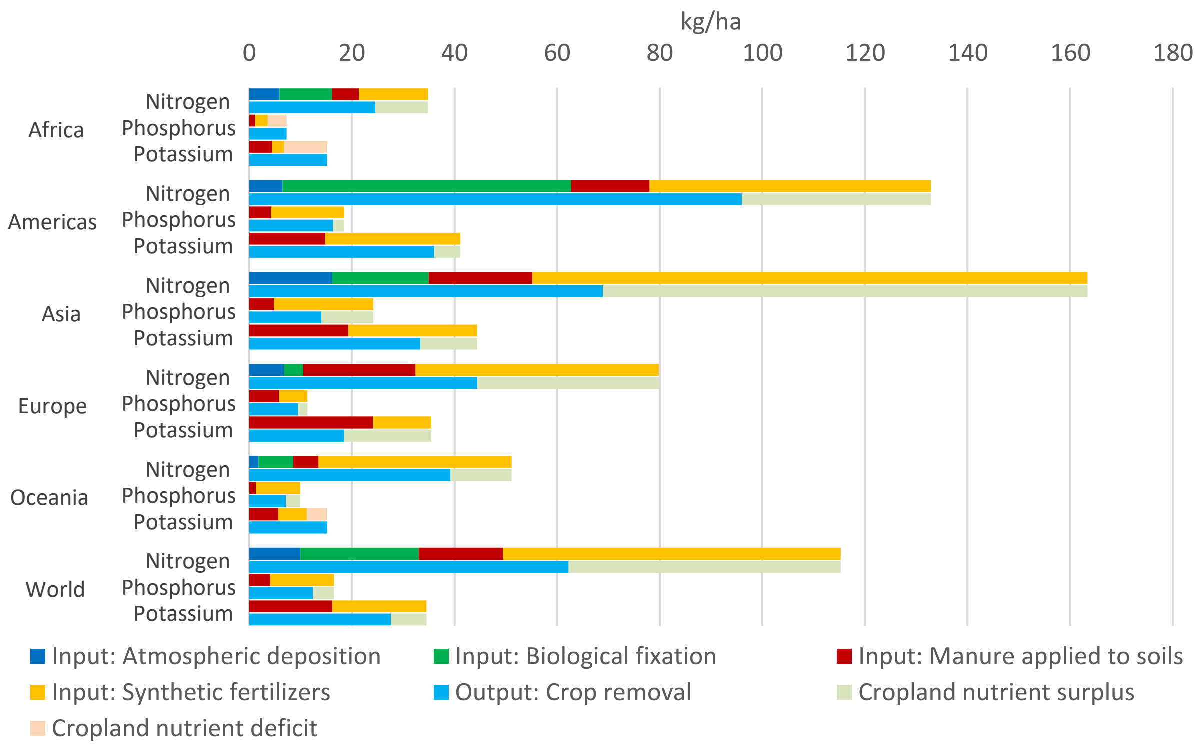
Source: FAO. 2022. FAOSTAT: Cropland nutrient budget. In: *FAO*. Rome. Cited November 2022. https://www.fao.org/faostat/en/#data/ESB

Figure 6: Cropland potassium budget per cropland area by region



Source: FAO. 2022. FAOSTAT: Cropland nutrient budget. In: *FAO*. Rome. Cited November 2022. https://www.fao.org/faostat/en/#data/ESB

Figure 7: Cropland nutrient budgets by region and nutrient, 2011–2020 average



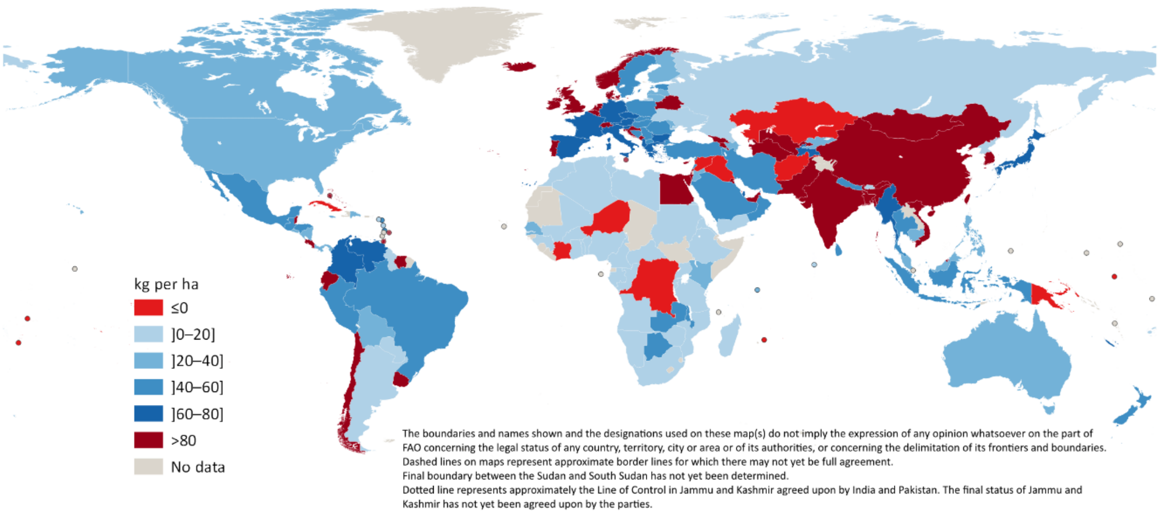
Source: FAO. 2022. FAOSTAT: Cropland nutrient budget. In: *FAO*. Rome. Cited November 2022. https://www.fao.org/faostat/en/#data/ESB

COUNTRY

Figures 8 and 9 show the large heterogeneity in the cropland nitrogen budget and use efficiency among countries in 2020. 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/year and the desired nitrogen use efficiency is between 50 percent and 90 percent. All countries that are classified as red in Figure 8 with nutrient deficits are also classified as red in Figure 9 with nitrogen use efficiencies greater than 90 percent. Most countries in Africa have cropland nitrogen budget values between 0 kg/ha and 40 kg/ha, while most European countries have a cropland nitrogen surplus between 40 kg/ha and 80 kg/ha. As suggested by Figure 4, some of the highest values are found in Asia.

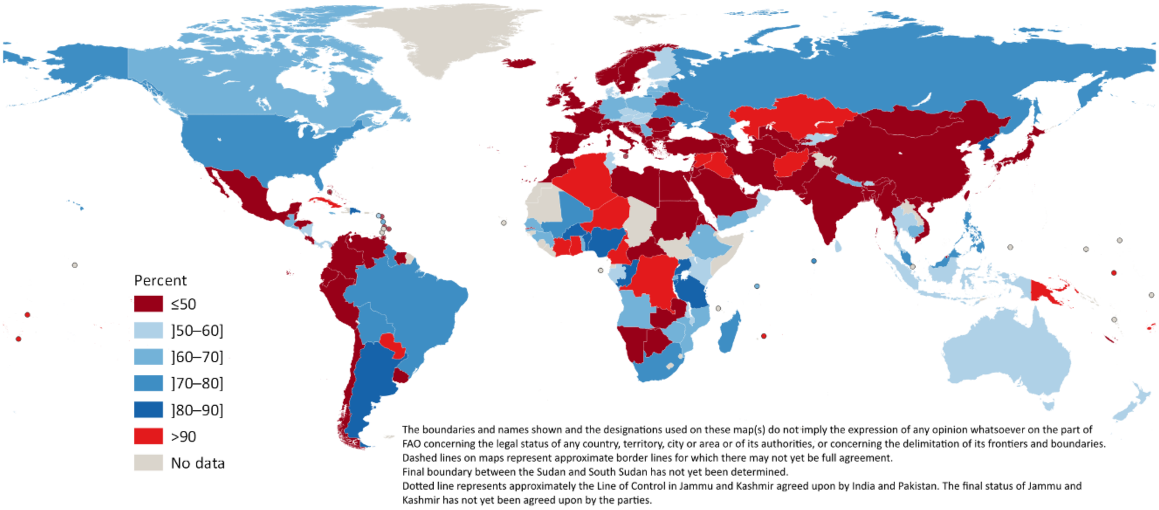
Combining Figures 8 and 9, some countries show differences between their status for the nitrogen budget versus their nitrogen use efficiency. For example, while Paraguay is on the lower end of the desired maximum for the cropland nitrogen budget, the country has an excessive nitrogen use efficiency indicating a possible risk of soil mining.

Figure 8: Cropland nitrogen budget per cropland area, 2020



Source: FAO. 2022. FAOSTAT: Cropland nutrient budget. In: *FAO*. Rome. Cited November 2022. https://www.fao.org/faostat/en/#data/ESB based on UN Geospatial. 2020. Map geodata [shapefiles]. New York, USA, UN.

Figure 9: Cropland nitrogen use efficiency, 2020

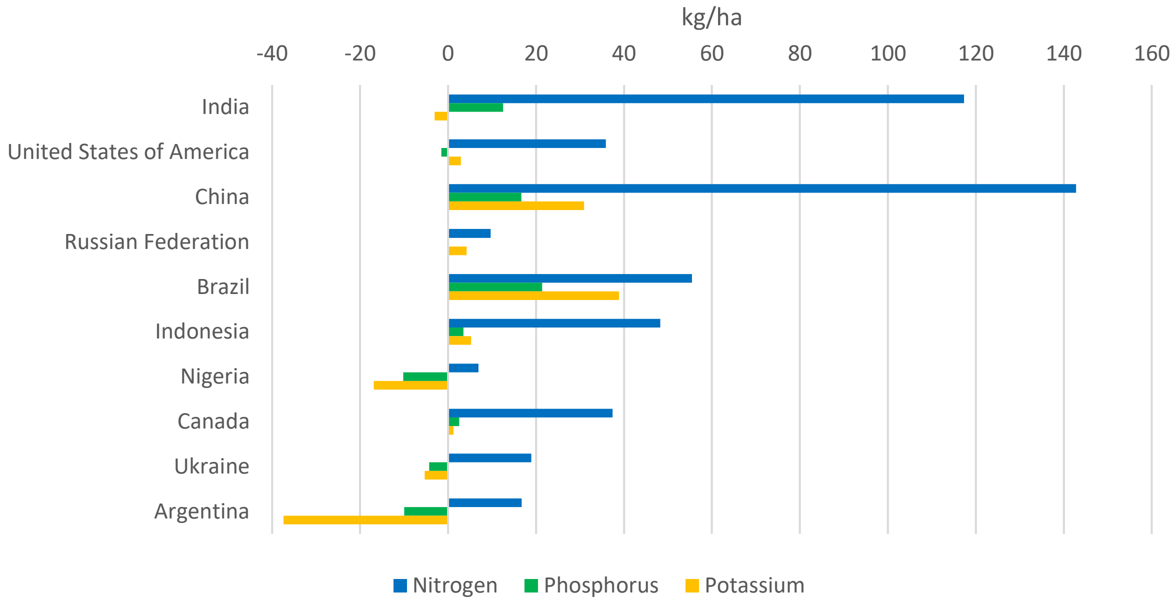


Source: FAO. 2022. FAOSTAT: Cropland nutrient budget. In: *FAO*. Rome. Cited November 2022. https://www.fao.org/faostat/en/#data/ESB based on UN Geospatial. 2020. Map geodata [shapefiles]. New York, USA, UN.

The countries with the largest cropland area show different profiles of the cropland nutrient budgets by nutrient, as shown on Figure 10. They also tend to have values that are multiples of the global average (for example twice the global average for nitrogen in China, or more than five times the global average for potassium in Brazil). China, Brazil, Indonesia and Canada have surpluses for all three nutrients, while India, the United States of America and the Russian Federation have surpluses for two nutrients (including nitrogen in all cases) and a small deficit in another. Nigeria, Ukraine and Argentina all have a surplus for nitrogen and deficits for phosphorus and potassium that can be sizeable: for Argentina, the cropland nutrient budget for potassium reaches -37 kg/ha.

Figure 11, displaying the bottom 10 countries for cropland nitrogen budget totals, shows that there are different pathways that countries may need to follow to achieve sustainable nutrient management. For example, although Kazakhstan has the largest deficit in absolute terms for nitrogen, the country has a potassium surplus indicating that the country may choose to prioritize the production of more nitrogen-fixating plants. Although the indicator does not consider baseline soil properties, the large nitrogen deficit for this county indicates a high risk of soil mining. Other countries with larger phosphorus or potassium deficits such as Côte d'Ivoire and the Democratic Republic of the Congo may choose to increase the composition of these nutrients in their mineral fertilizer application.

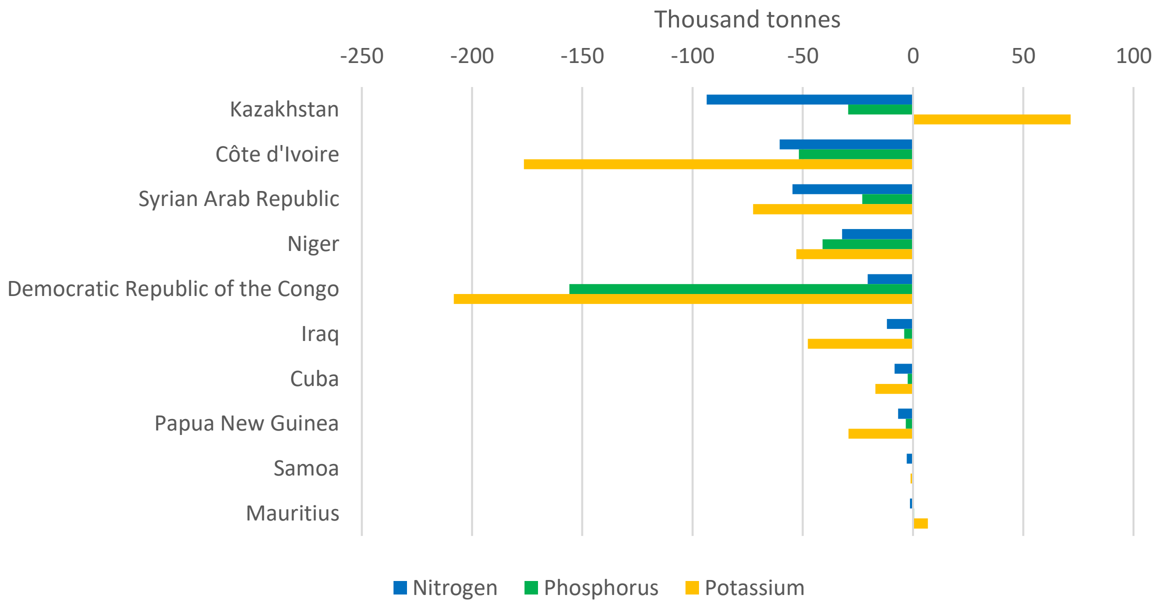
Figure 10: Cropland nutrient budget per cropland area by nutrient, selected countries, 2020



Note: Countries are listed in descending order of cropland area, from India (first) to Argentina (tenth).

Source: FAO. 2022. FAOSTAT: Cropland nutrient budget. In: *FAO*. Rome. Cited November 2022. https://www.fao.org/faostat/en/#data/ESB

Figure 11: Cropland nitrogen budget, bottom countries, 2020 (with phosphorus and potassium)



Source: FAO. 2022. FAOSTAT: Cropland nutrient budget. In: *FAO*. Rome. Cited November 2022. https://www.fao.org/faostat/en/#data/ESB

EXPLANATORY NOTES

- The 2022 update of the cropland nutrient budget 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 of the University of Maryland contributed to the fraction of synthetic fertilizers and manure on cropland and atmospheric deposition data. Cameron Ludemann provided updated nutrient removal coefficients and nutrient ratios for manure. Rasmus Einarsson contributed with updated data for nitrogen biological fixation. The group contributed to the overall quality of the data and text within the analytical brief. The FAOSTAT domain "Cropland nutrient budget" disseminates nutrient flows in a given country and year. The cropland nutrient budget can give an indication of nutrient use efficiency, as it can help quantify excess nutrients leading to environmental risks, for instance, GHG emissions or pollution from volatilization and leaching/runoff. It can also signal cropland nutrient deficits that limit crop production.
- The nutrient budget (NB) is calculated as the sum of inputs: synthetic fertilizers (SF) multiplied by the fraction of fertilizer applied to cropland (CF), manure applied to soils (MAS), nitrogen deposition (ND), and biological fixation (BF) minus outputs: crop removal (CR).
- The definition of cropland corresponds to that of FAOSTAT.
- Data for synthetic 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)".
- Data for synthetic fertilizers for the International Fertilizer Association (IFA) 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 N, 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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