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FAOSTAT ANALYTICAL BRIEF 74

Cropland nutrient balance

Global, regional and country trends

1961–2021

>> FAO Statistics Division

HIGHLIGHTS

- → **At the global level, the cropland nutrient surplus in 2021 was 82 million tonnes (Mt) of nitrogen (N), 8 Mt of phosphorus (P), and 12 Mt of potassium (K) corresponding to 52 kg N per ha, 5 kg P per ha, and 7 kg K per ha of cropland.**
- → **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).**
- → **High levels of nitrogen, phosphorus and potassium use efficiencies in Africa indicate soil nutrient mining in many parts of the region.**
- → **The Americas have accounted for more than half of the global total nitrogen from biological fixation since the 2000s.**
- → **In Europe, a large proportion of total nutrient inputs come from manure applied to soils, averaging 34 percent for N, 41 percent for P, and 58 percent for K over the whole period.**
- → **At the global level, the efficiency in the use of N, P and K for crop production has increased steadily since the mid-1980s.**

FAOSTAT CROPLAND NUTRIENT BALANCE

BACKGROUND

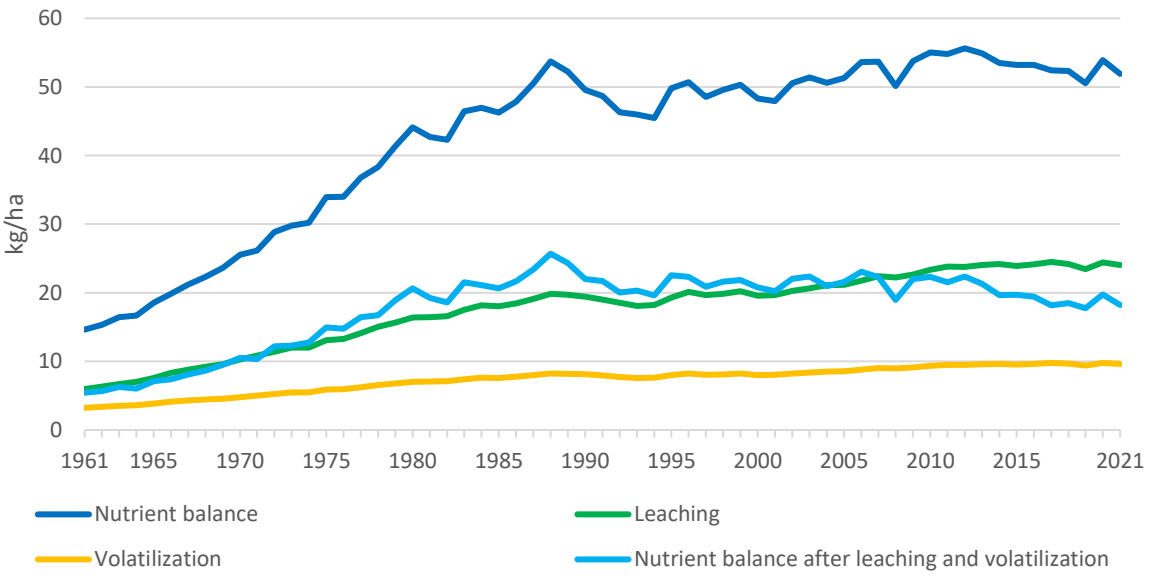
Cropland nutrient balances are an important indicator of nutrient flows that can signal an excess or insufficiency on cropland. The three main nutrients for plant growth are nitrogen (N), phosphorus (P), and potassium (K). Excess nutrient loads on cropland represent environmental risks such as nitrate leaching, erosion or runoff into water bodies and ammonia volatilization (NH_3) or emissions of nitrous oxide (N_2O) and 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 for phosphorus and potassium), *manure applied to soils*, *biological fixation*, and *atmospheric deposition (both reduced and oxidized compounds)*. As part of the 2023 update, data has also been included for *seed* (which contributes a small percentage to global inputs, representing 1 percent of total inputs for the world). The output from cropland is in the form of *crop removal* from harvest. The difference between these inputs and outputs is the *nutrient balance*. 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 nitrates) 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 incorporating leaching and volatilization as losses in the nitrogen balance results in a reduction by 37 million tonnes, or 25 kg per hectare (ha) of cropland (58 percent) on average for the whole period. Furthermore, while the nitrogen surplus has increased by 15 percent in the most recent decade compared to the 1990s, including these loss components leads to a slight reduction by 4 percent over the same period. The results analysed in this brief for the nutrient surplus, without accounting for leaching/volatilisation, give a better indication of environmental risks.

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. Lastly, country results are presented for the cropland nutrient balance total.

Figure 1: Global nitrogen balance per cropland area with and without leaching and volatilization

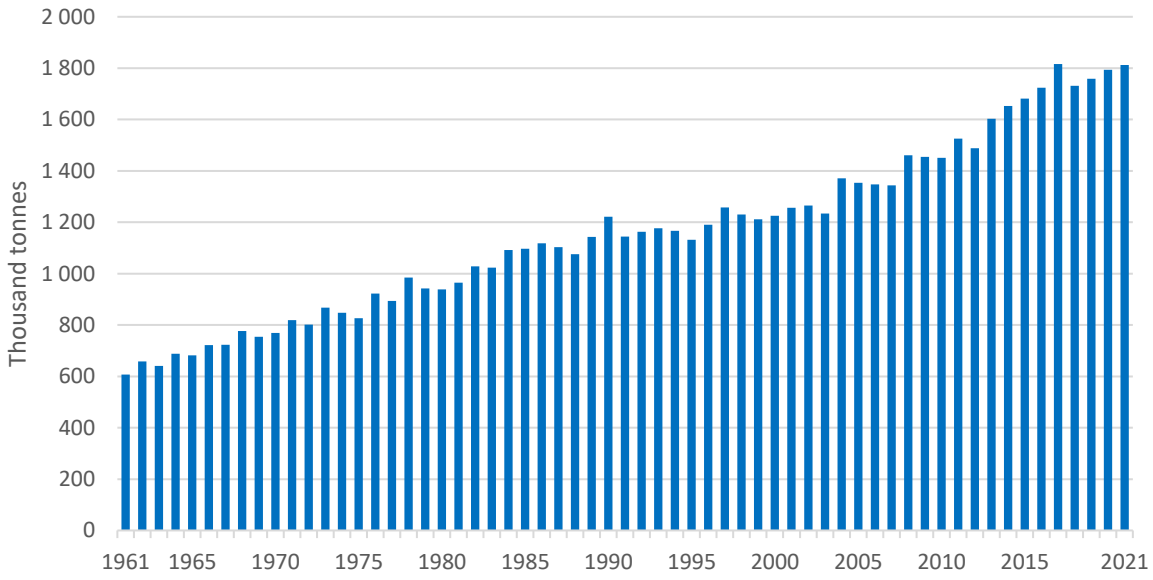


Source: FAO. 2023. Cropland nutrient balance. In: *FAOSTAT*. Rome. [Cited December 2023]. https://www.fao.org/faostat/en/#data/ESB

GLOBAL

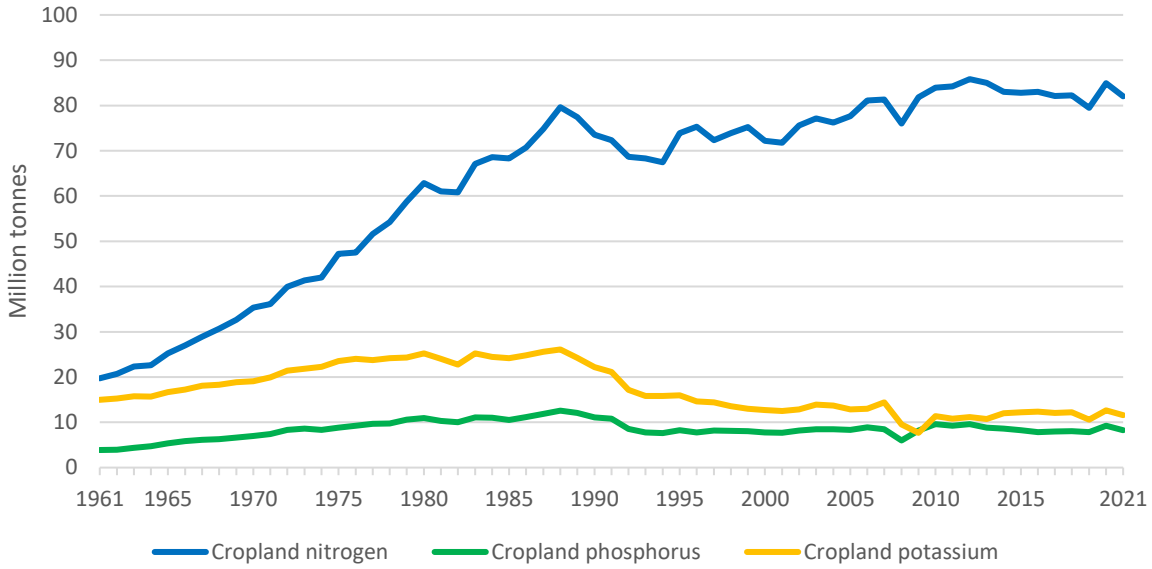
At the global level, the cropland nutrient surplus in 2021 was 82 million tonnes (Mt) of N, 8 Mt of P and 12 Mt of K distributed over cropland at rates of 52 kg N per ha (compared to a desired maximum N surplus of 80 kg per ha per year [EU Nitrogen Expert Panel, 2015]), 5 kg P per ha, and 7 kg K per ha. Figure 3 shows that there was a substantial, 3.3-fold increase in the total cropland nitrogen balance compared with the 1960s, while the phosphorus cropland balance remained nearly neutral since the 1990s and the potassium balance declined by 28 percent over the same period. Seed accounted for an average of 1 000 tonnes of nitrogen per year over the entire time period (Figure 2). 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 5.8 from 17 Mt in the 1960s to 100 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 96 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 17 Mt). 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 seed input



Source: FAO. 2023. Cropland nutrient balance. In: *FAOSTAT*. Rome. [Cited December 2023]. https://www.fao.org/faostat/en/#data/ESB

Figure 3: Global cropland nutrient balance by nutrient



Source: FAO. 2023. Cropland nutrient balance. In: *FAOSTAT*. Rome. [Cited December 2023]. https://www.fao.org/faostat/en/#data/ESB

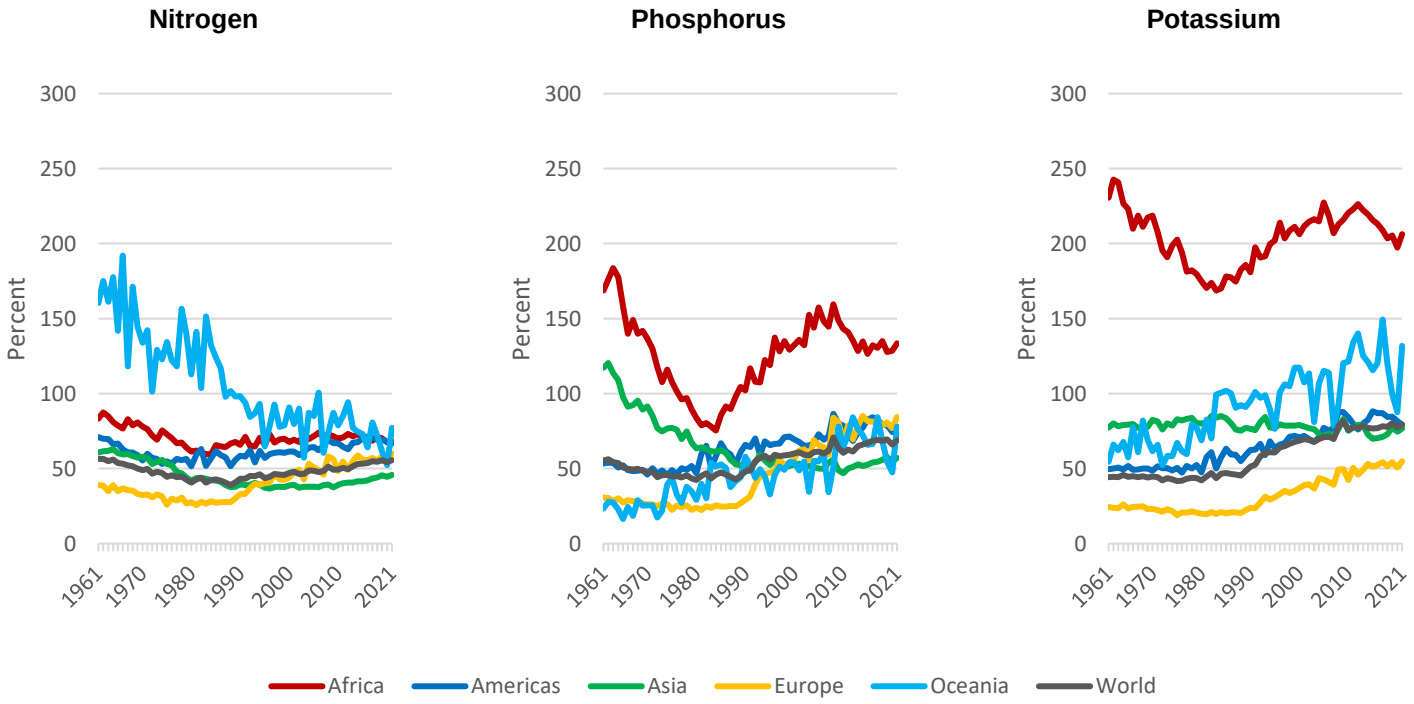
Nutrient use efficiency, calculated as the ratio of nutrient removal from crops to total nutrient input, is a measure of how well crops use available nutrients. High values of nitrogen use efficiency (greater than 90 percent) indicate risks of nutrient mining of soils, while low values (less than 50 percent) indicate risks of insufficient nutrient use (EU Nitrogen Expert Panel, 2015). Nitrogen use efficiency declined between the 1960s (54 percent) and the 1980s (42 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 52 percent in the 1960s and 45 percent in the 1980s, but the efficiency in the most recent decade is at an all-time high of 67 percent. Lastly, potassium use efficiency remained stable until 1990, with values of 45 percent in the 1960s and 46 percent in the 1980s before increasing to 61 percent in the 1990s and reaching a record high 78 percent in the most recent decade. The average nutrient use efficiency over the whole period for the world was 48 percent for nitrogen, 55 percent for phosphorus, and 58 percent for potassium (Figure 4), which is below the 2021 levels for all nutrients (56 percent, 69 percent and 79 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, making up for 32 percent of total inputs in the 1960s and 56 percent in the most recent decade for nitrogen, increasing from 58 percent to 75 percent for phosphorus, and from 29 percent to 54 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, it contributed to an average of 57 percent of total inputs for potassium.

REGIONAL

Over the whole period, **Africa** was above the world average for nitrogen use efficiency (71 percent) and had the highest phosphorus and potassium use efficiencies (125 percent and 204 percent, respectively), indicating that cropland in the region is running a deficit for these two nutrients. The nutrient use efficiencies for the region in 2021 were 68 percent for nitrogen, 133 percent for phosphorus, and 206 percent for potassium. The **Americas** were above the world average, although closer than most of the regions, for cropland nutrient use efficiencies (62 percent for nitrogen, 63 percent for phosphorus, and 64 percent for potassium). The nutrient use efficiencies for the Americas in 2021 were 67 percent for nitrogen, 74 percent for phosphorus, and 79 percent for potassium. **Asia** used nitrogen with almost the same efficiency as the world (45 percent) but more efficiently for phosphorus (65 percent) and potassium (78 percent). The nutrient use efficiencies for Asia in 2021 were 46 percent for nitrogen, 57 percent for phosphorus, and 77 percent for potassium. The nutrient efficiency in **Europe** was below the global average for nutrients, 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 2021 were 60 percent for nitrogen, 84 percent for phosphorus, and 55 percent for potassium. Trends in Europe and in turn for the world can partially be explained by 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. In **Oceania**, nitrogen use efficiency began high in the 1960s (160 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 70 percent. Potassium use efficiency (92 percent over the whole period) remained above the world average. The nutrient use efficiencies for Oceania in 2021 were 77 percent for nitrogen, 78 percent for phosphorus, and 132 percent for potassium.

Figure 4: Nutrient use efficiency by region



Source: FAO. 2023. Cropland nutrient balance. In: *FAOSTAT*. Rome. [Cited December 2023]. https://www.fao.org/faostat/en/#data/ESB

Figures 5 to 8 show that the trends and levels of the cropland nutrient surplus per hectare of cropland differed significantly by region between 1961 and 2021.

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 (-1 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 contribution of mineral fertilizers to the total balance rose until the 1990s for N (from 21 percent in the 1960s to 42 percent in the 1980s for N, from 66 percent to 78 percent for P, and from 28 percent to 40 percent for K) after which it began to decline (reaching 39 percent for N, 67 percent for P and 35 percent for K in the most recent decade). The cropland nutrient balance for the region in 2021 was 13 kg per ha for N, -1 kg per ha for P, and 8 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 (213 thousand tonnes [kt]) exceeded mineral fertilizer N (205 kt), mainly due to large areas of soybean cropping. The region is near the world average for nutrient surpluses per ha of cropland (31 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 nitrogen, 26 percent for phosphorus, and 44 percent for potassium. The cropland nutrient balance for the region in 2021 was 48 kg per ha for N, 5 kg per ha for P, and 9 kg per ha for K.

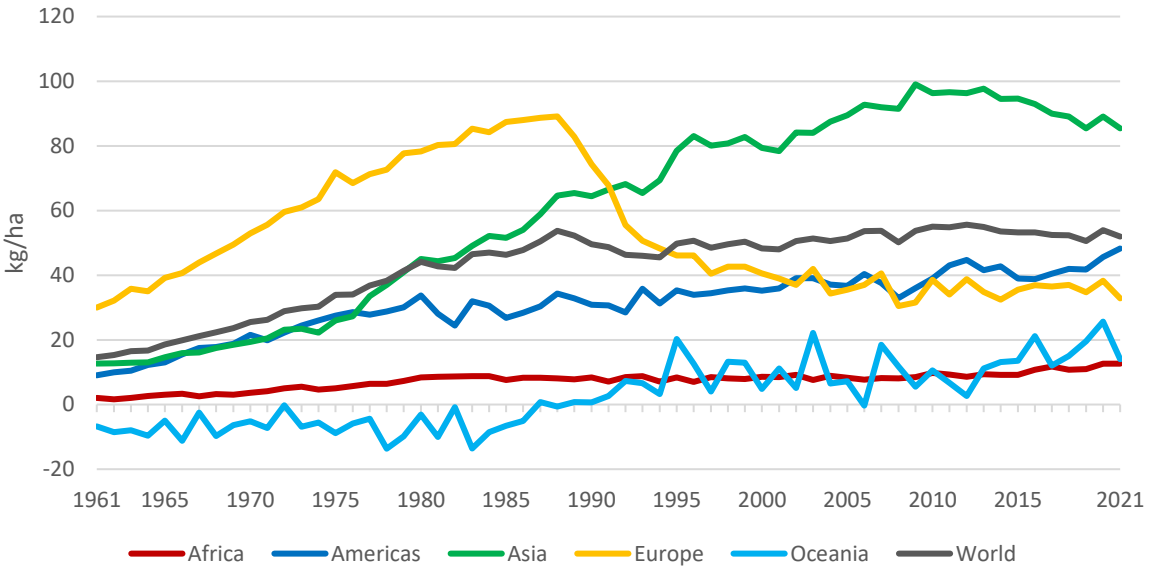
Asia was the biggest contributor of total nutrient inputs to the global total in the most recent decade, accounting for approximately half of total nutrients applied for N (52 percent), P (55 percent) and K (48 percent). Although the region has the highest nitrogen surplus per unit area as of the 1990s (74 kg N per ha of cropland) and phosphorus balance per unit area as of the 2000s (10 kg P per ha of cropland), this is not true for the potassium balance per unit area, which averaged 6 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 (61 percent for N, 59 percent for P, and 51 percent for K). The cropland nutrient balance for the region in 2021 was 85 kg per ha for N, 10 kg per ha for P, and 11 kg per ha for K.

For **Europe**, a large proportion of total nutrient inputs come from manure applied to soils, averaging 34 percent for N, 41 percent for P, and 58 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: -41 percent for N, -56 percent for P and -43 percent for K. Although the region moved below the world average for the cropland nitrogen and phosphorus balances per unit area in the 2000s (37 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 36 kg K per ha per year). The cropland nutrient balance for the region in 2021 was 33 kg per ha for N, 2 kg per ha for P, and 15 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, from the 1960s to the 1970s, the contribution of mineral fertilizers to total inputs increased from 34 percent to 44 percent to become greater than that of manure applied to soils, which reduced from 41 percent to 35 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 potassium was high (averaging 58 percent over the whole

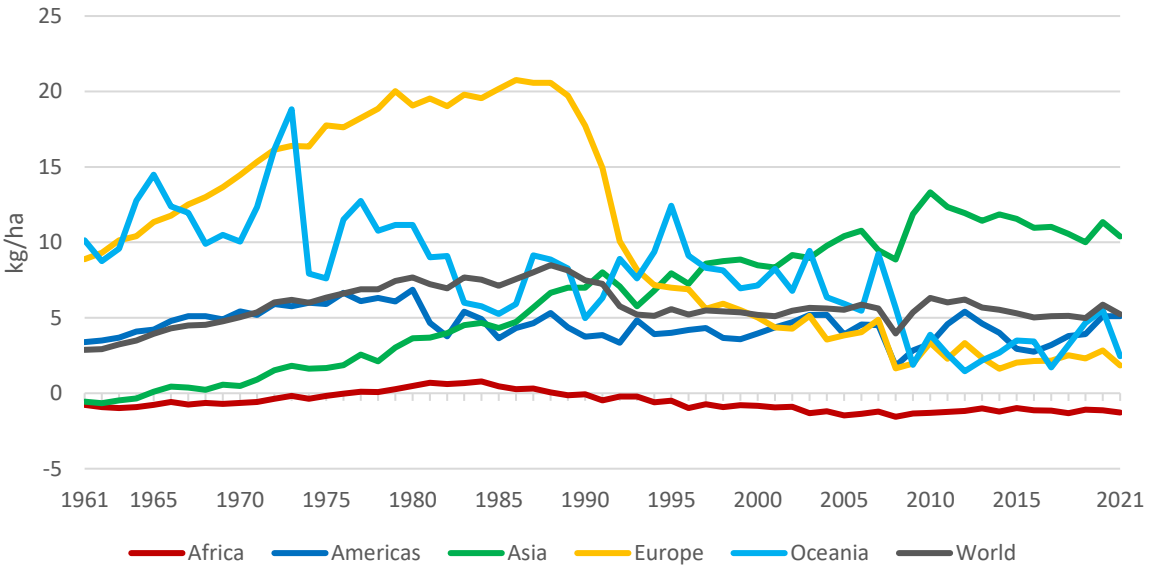
period). The cropland nutrient balance for the region in 2021 was 14 kg per ha for N, 2 kg per ha for P, and -4 kg per ha for K.

Figure 5: Cropland nitrogen balance per cropland area by region



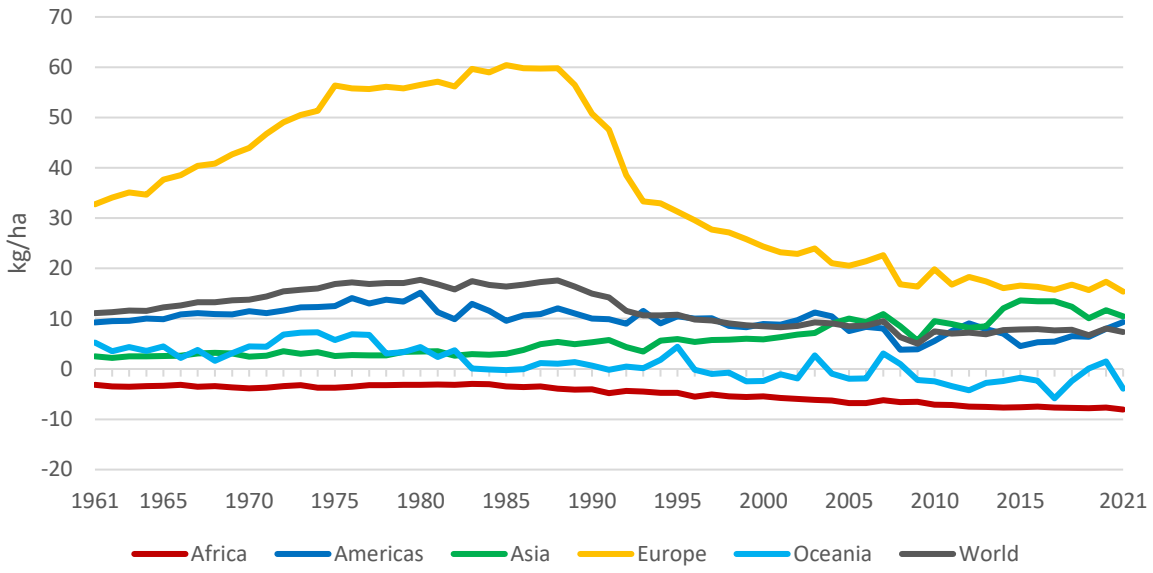
Source: FAO. 2023. Cropland nutrient balance. In: *FAOSTAT*. Rome. [Cited December 2023]. https://www.fao.org/faostat/en/#data/ESB

Figure 6: Cropland phosphorus balance per cropland area by region



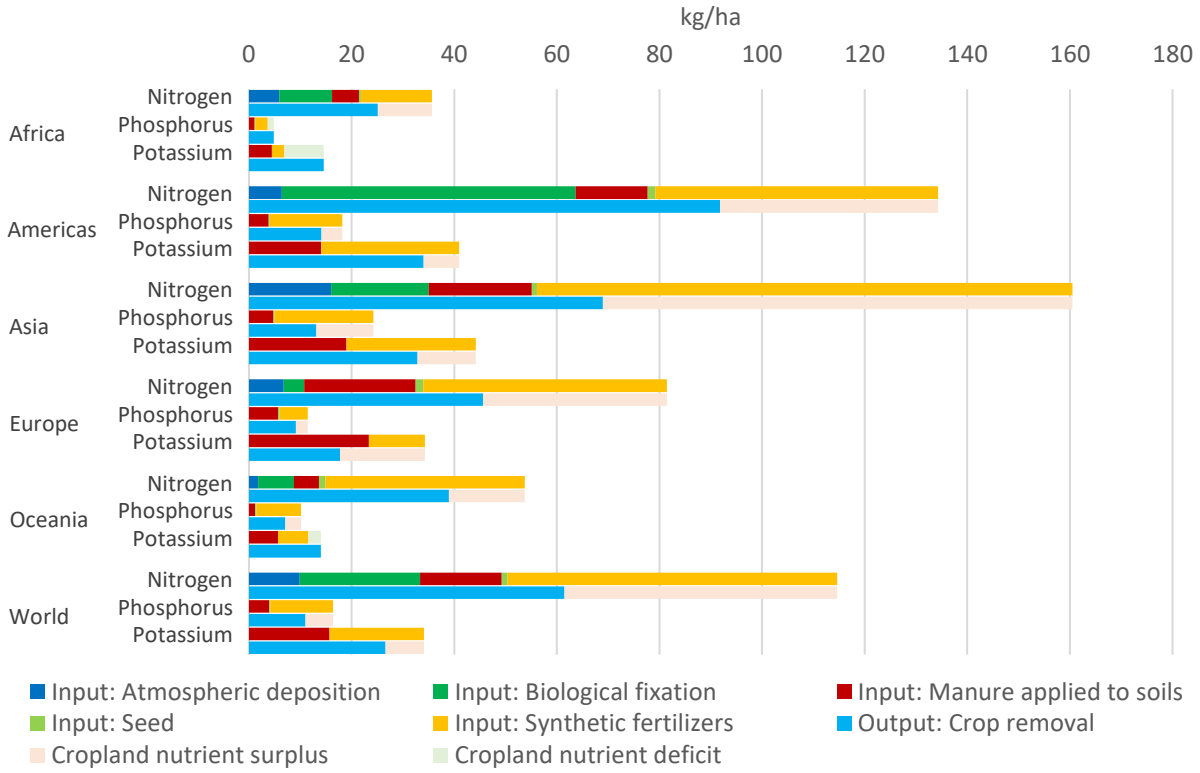
Source: FAO. 2023. Cropland nutrient balance. In: *FAOSTAT*. Rome. [Cited December 2023]. https://www.fao.org/faostat/en/#data/ESB

Figure 7: Cropland potassium balance per cropland area by region



Source: FAO. 2023. Cropland nutrient balance. In: *FAOSTAT*. Rome. [Cited December 2023]. https://www.fao.org/faostat/en/#data/ESB

Figure 8: Cropland nutrient balances by region and nutrient, 2012–2021 average



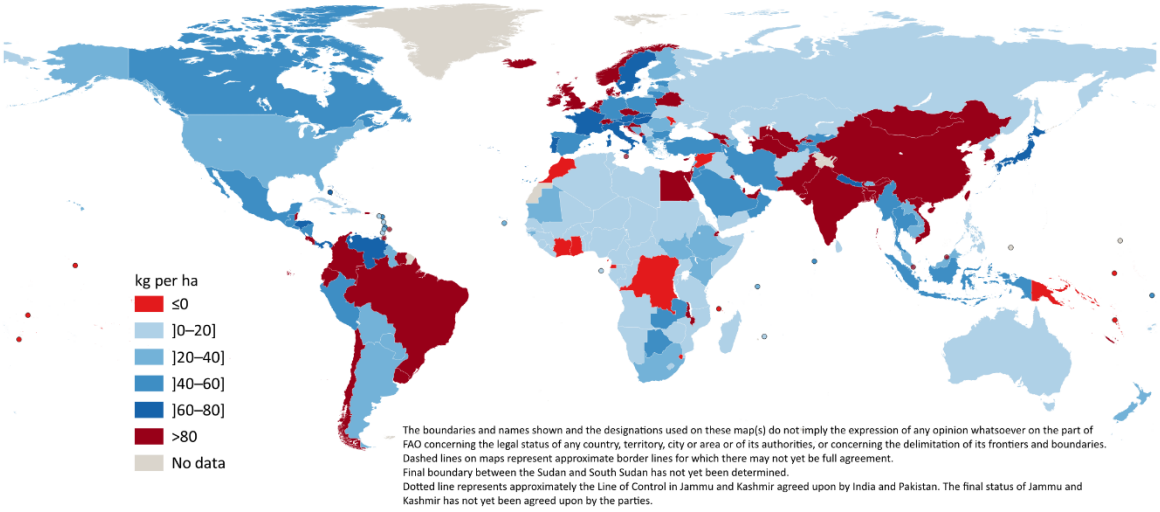
Source: FAO. 2023. Cropland nutrient balance. In: *FAOSTAT*. Rome. [Cited December 2023]. https://www.fao.org/faostat/en/#data/ESB

COUNTRY

Figures 9 and 10 show the large heterogeneity in the cropland nitrogen balance per area of cropland and use efficiency among countries in 2021. 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.

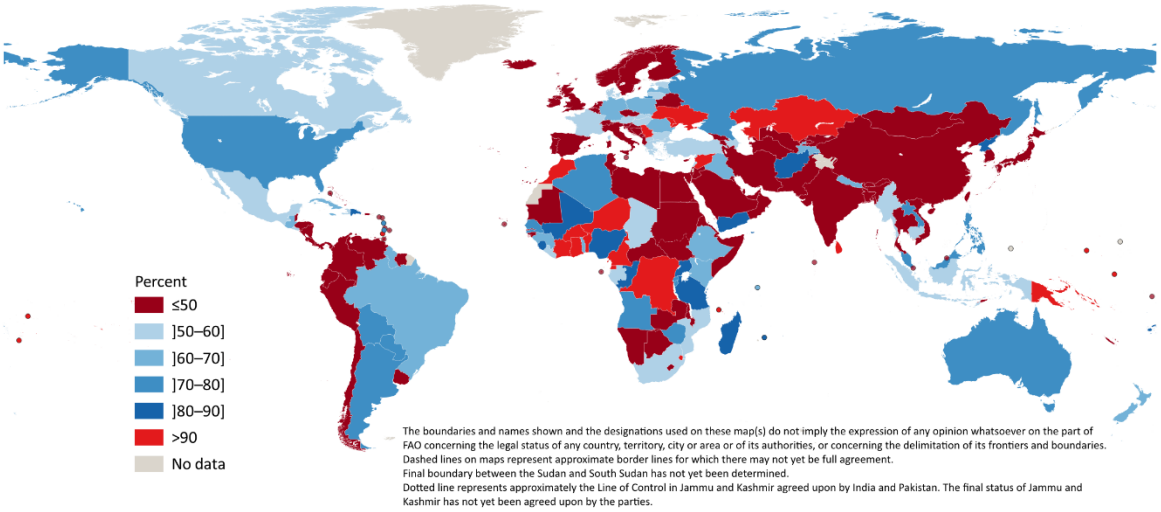
Combining Figures 9 and 10, some countries show differences between their status for the nitrogen balance versus their nitrogen use efficiency. For example, while Brazil is on the upper end of the cropland nitrogen balance, the country has a nitrogen use efficiency within the desired range, indicating 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). The nitrogen use efficiency can also be combined with land use productivity to compute a sustainable nitrogen management index (Zhang *et al.*, 2022).

Figure 9: Cropland nitrogen balance per cropland area, 2021



Source: FAO. 2023. Cropland nutrient balance. In: *FAOSTAT*. Rome. [Cited December 2023]. https://www.fao.org/faostat/en/#data/ESB based on UN Geospatial. 2020. Map geodata [shapefiles]. New York, USA, UN.

Figure 10: Cropland nitrogen use efficiency, 2021



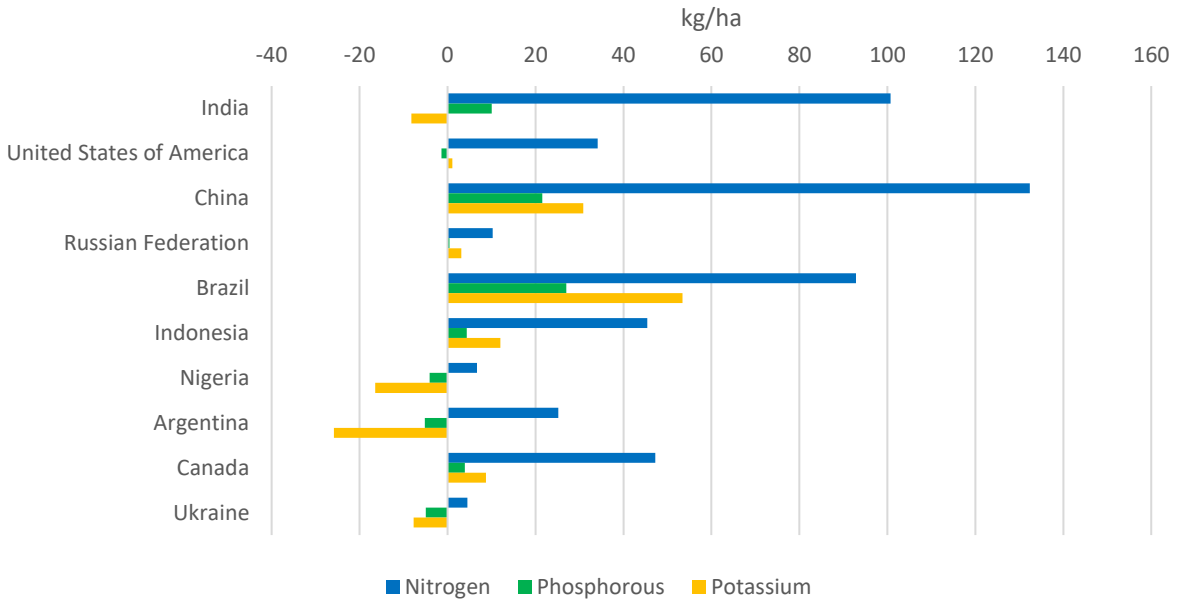
Source: FAO. 2023. Cropland nutrient balance. In: *FAOSTAT*. Rome. [Cited December 2023]. https://www.fao.org/faostat/en/#data/ESB based on UN Geospatial. 2020. Map geodata [shapefiles]. New York, USA, UN.

The countries with the largest cropland area[1] show different profiles of the cropland nutrient balances by nutrient for 2021, as shown on Figure 11. Of these countries, India, China 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 Russian Federation, Brazil, Indonesia and Canada have surpluses for all three nutrients, while India and the United States of America have surpluses for two nutrients (including nitrogen in all cases) and a small deficit in another. Argentina, Nigeria and Ukraine all have surpluses for nitrogen and deficits in the other two nutrients.

Figure 12, displaying the bottom 10 countries for cropland nitrogen balance totals for 2021, shows that there are different pathways that countries may need to follow to achieve sustainable nutrient management. While all the countries shown in the figure have deficits for all three nutrients, the magnitude of these deficits differs by nutrient within countries. For example, all these countries have larger relative deficits for potassium, suggesting that the promotion of nitrogen interventions alone will not be sufficient. These differences can help countries to address specific nutrients by altering compositions of fertilizers.

[1] An upwards revision for Argentina in 2023 changed the ranking of Canada, Ukraine and Argentina for cropland.

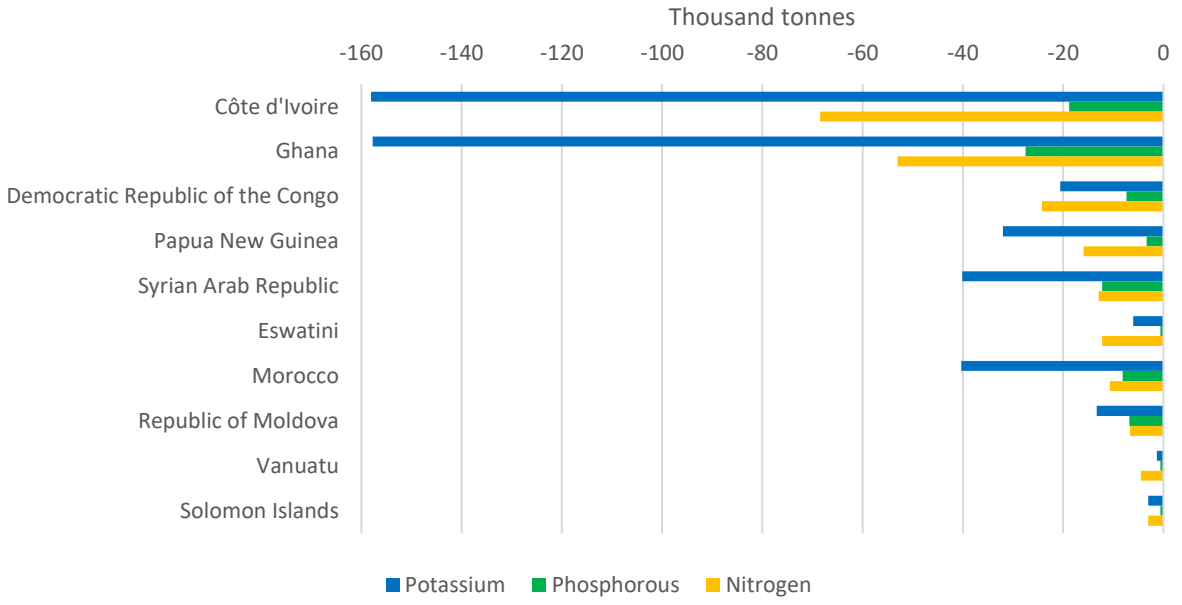
Figure 11: Cropland nutrient balance per cropland area by nutrient, selected countries, 2021



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

Source: FAO. 2023. Cropland nutrient balance. In: *FAOSTAT*. Rome. [Cited December 2023]. https://www.fao.org/faostat/en/#data/ESB

Figure 12: Cropland nitrogen balance, bottom countries, 2021 (with phosphorus and potassium)



Source: FAO. 2023. Cropland nutrient balance. In: *FAOSTAT*. Rome. [Cited December 2023]. https://www.fao.org/faostat/en/#data/ESB

EXPLANATORY NOTES

- The 2023 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 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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