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FAOSTAT ANALYTICAL BRIEF 20

Soil nutrient budget

Global, regional and country trends, 1961–2018

>> FAO Statistics Division

HIGHLIGHTS

- → **FAO released for the first time soil nutrient budget data for 205 countries over the 1961–2018 period. The data help quantify soil nutrient surpluses (leading to environmental risks) or deficits (which limit crop yield).**
- → **At the global level, the soil nutrient budget in 2018 over cropland was 103 million tonnes distributed over cropland at a rate of 65 kg per ha.**
- → **The soil nutrient budget has increased substantially from the 1960s with a 4.0-fold increase in the total budget.**
- → **Synthetic fertilizers are taking an ever increasingly important role, making up for 36 percent of total nitrogen inputs in the 1960s and 59 percent in the 2010s.**
- → **Asia was the biggest contributor of total nitrogen inputs to the global total in the 2010s, accounting for 50 percent of total nitrogen input.**
- → **The Americas were responsible for more than 70 percent of total nitrogen from biological fixation since the 2000s.**
- → **Since the 2000s, Africa has the highest nitrogen use efficiency at above 60 percent.**
- → **The top 10 countries with the highest soil nutrient budget per unit area for the 2010s are Trinidad and Tobago, Malta, Luxembourg, Djibouti, Belgium, Switzerland, the United Arab Emirates, Egypt, Barbados, and the United Kingdom of Great Britain and Northern Ireland.**

FAOSTAT SOIL NUTRIENT BUDGET

BACKGROUND

Soil nutrient budgets are an important indicator of nutrient flows that can signal an excess or insufficiency in the soil. The three main nutrients for plant growth are nitrogen, phosphorus, and potassium. Excess nutrient loads in the soil present environmental risks such as leaching into water sources and volatilization in the form of greenhouse gas (GHG) emissions. An insufficient nutrient load indicates a limiting factor in maximizing the yield potential of the soil.

This analytical brief focuses on the nutrient nitrogen. The key inputs into the nitrogen nutrient budget are *synthetic fertilizers*, *manure applied to soils*, *biological fixation*, and *atmospheric deposition.*[1] The output from the soil is in the form of *crop removal* from harvest. The difference between these inputs and outputs is the *soil nutrient budget*. The soil nutrient budget, as presented here, does not account

[1] See the metadata of the ESB domain for definitions of the different inputs: http://fenixservices.fao.org/faostat/static/documents/RFN/RFN_EN_README.pdf

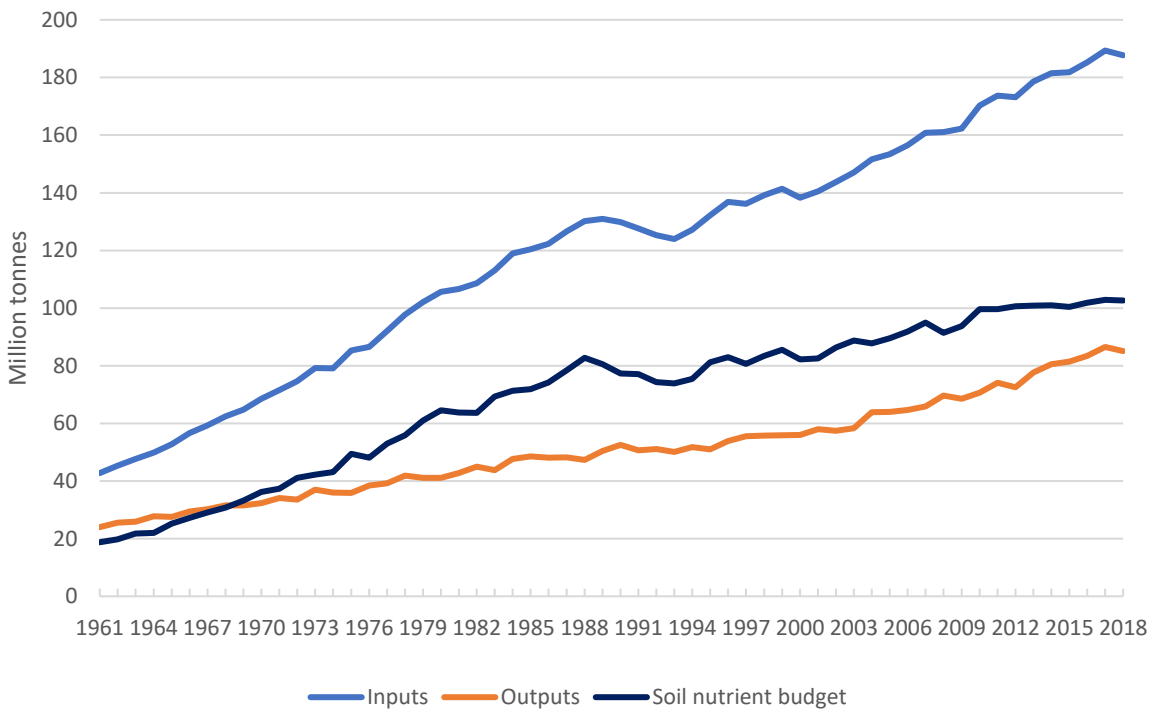
for the heterogeneity of baseline soil nutrient properties across countries nor nutrient retention/mining across successive periods; the indicator also does not account for losses in the form of emissions and leaching into water bodies. Nonetheless, trends over time of the soil nutrient budget give an important indication of how efficiently agricultural inputs are being applied with respect to outputs.

In this analytical brief, nutrient budgets are presented both as total nutrient flows and per area of cropland. Global and regional trends are analyzed along with highlights of the most important contributors to the overall budget and how these main contributors have changed over time. Lastly, the top 10 countries for the soil nutrient budget per unit area and bottom 10 countries for the soil nutrient budget total are presented.

GLOBAL

At the global level, the soil nutrient budget in 2018 over cropland was 103 million tonnes distributed over cropland at a rate of 65 kg per ha. This substantial, 4.0-fold increase in the total budget. compared with the 1960s (see Figure 1) mainly comes from a growth in the use of synthetic fertilizers (with a 5.5-fold increase from 19 million tonnes in the 1960s to 106 million tonnes in the 2010s) and a substantially lower increase in crop uptake (with a 2.8-fold increase from 28 million tonnes in the 1960s to 79 million tonnes in the 2010s). Nitrogen use efficiency, a measure of how well crops use available nutrients (calculated as the nitrogen removal from crops over the total nitrogen input), has decreased from 53 percent in the 1960s to 44 percent in the 2010s (see Figure 4). In more recent years, the global soil nutrient budget has leveled off, remaining stable from 2010 to 2018 with an increase of only 1 million tonnes during this period.

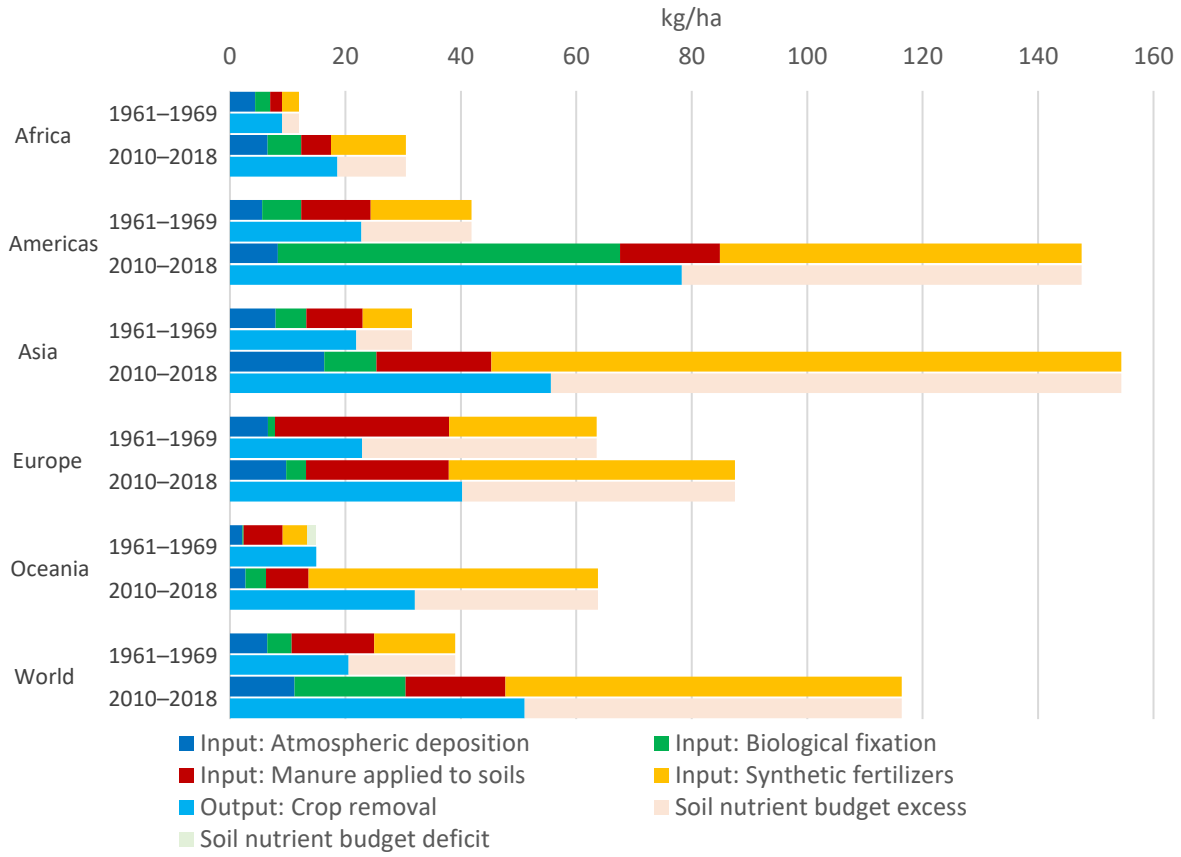
Figure 1: Global soil nutrient budget with inputs and outputs, 1961–2018



Source: FAOSTAT Soil nutrient budget, 2021.

The relative importance of the different inputs contributing to the global total soil nutrient budget also changed since the 1960s, with synthetic fertilizers taking an ever increasingly important role, making up for 36 percent of total inputs in the 1960s and 59 percent in the 2010s. While the amount of manure applied to soils increased (from 20 million tonnes to 27 million tonnes), its contribution to the global total decreased (from 37 percent to 15 percent). The share of total inputs from atmospheric deposition decreased from 17 percent in the 1960s to 10 percent in the 2010s (see Figure 2) and was 11 kg/ha of cropland in 2018, while the share coming from biological fixation increased from 11 percent to 17 percent over the same period, reaching 22 kg/ha of cropland in 2018.

Figure 2: Global and regional soil nutrient budgets per cropland area by input and output type, 1960s and 2010s



Source: FAOSTAT Soil nutrient budget, 2021.

REGIONAL

As seen in Figure 3 and Table 1, the trends and levels of the soil nutrient budget per hectare of cropland differed significantly by region between 1961 and 2018.

Asia was the biggest contributor of total nitrogen inputs to the global total in the 2010s, accounting for 50 percent of total nitrogen input. The soil nutrient budget peaked at 101 kg per ha of cropland in 2010 and dropped slightly to 96 kg per ha in 2018. From the 1960s to the 1970s, the region shifted from applying more manure to soils to more synthetic nitrogen – across these decades the share of total

inputs over cropland from manure dropped from 31 percent to 23 percent while the share from synthetic fertilizers rose from 27 percent to 48 percent. Nitrogen uptake in crops rose steadily from 22 kg per ha of cropland in the 1960s to 56 kg/ha in the 2010s, but not at the same rate as nitrogen inputs, causing the nitrogen use efficiency to drop from 69 percent to 36 percent (Figure 4). Inputs from biological fixation rose from nearly 2.7 million tonnes in the 1960s to 5.2 million tonnes in the 2010s, and atmospheric deposition rose from 4.0 million tonnes to 9.5 million tonnes over the same period.

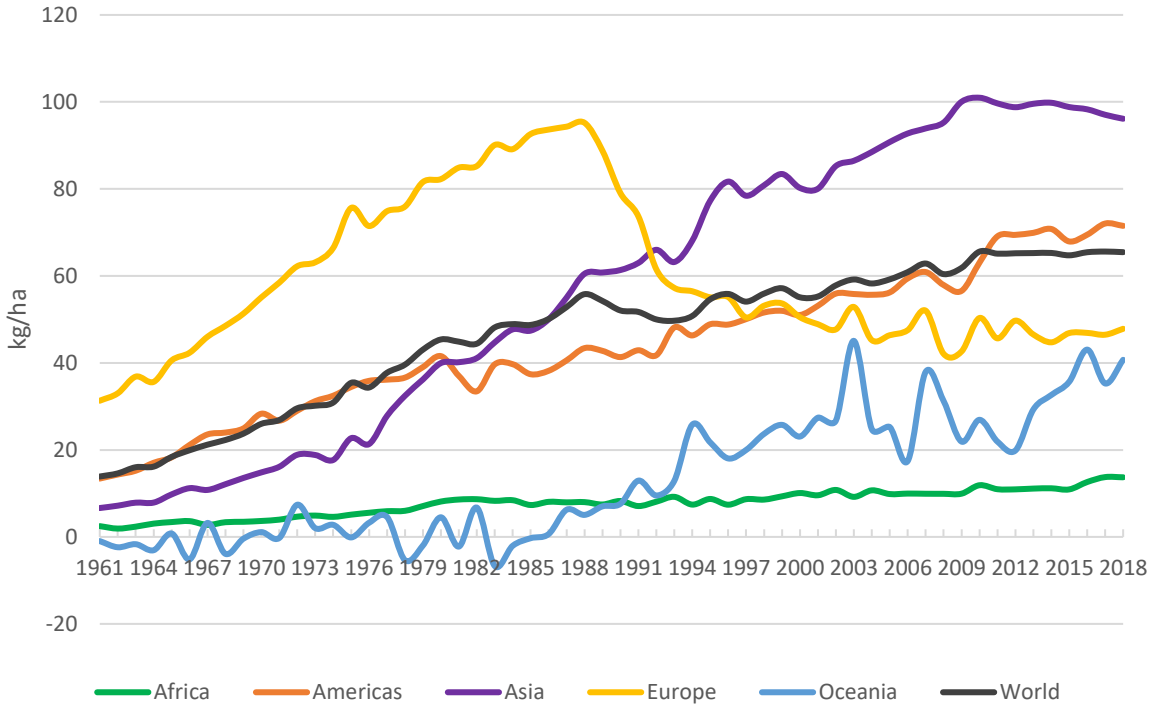
Oceania was the only region to start off with a virtual zero nitrogen budget over cropland in the 1960s, with crop nitrogen uptake (326 000 tonnes) slightly exceeding total inputs (294 000 tonnes). In 2018, the soil nutrient budget was 41 kg per ha of cropland. The region had a small contribution to the world total, accounting for only 1 percent of total inputs and outputs across the period. Biological fixation and nitrogen deposition together accounted for 10 percent of total inputs in the 2010s and the flows over cropland were 4 and 3 kg per ha, respectively. Up until the 2000s, the region had the highest nitrogen use efficiency, as compared to the other regions. A significant increase in the soil nutrient budget occurred in the 2010s, from 27 kg per ha of cropland in 2010 to 41 kg per ha of cropland in 2018, mostly attributable to a rise in synthetic nitrogen.

The Americas have accounted for more than 70 percent of total nitrogen from biological fixation since the 2000s. The region maintained a very steady nitrogen use efficiency of around 50 percent since 1961. In the most recent years, the nutrient budget increased from 63 kg per ha of cropland in 2010 to 72 kg/ha in 2018, a rise attributable to biological fixation which was multiplied by nearly 10 since 1961. Increases for other inputs in the region were smaller: atmospheric deposition went from 1.8 to 3.1 million tonnes, manure applied to soils from 4.0 to 6.4 million tonnes, and synthetic fertilizer from 5.8 to 23.1 million tonnes.

Africa was the only region in which atmospheric deposition accounted for the largest share of total inputs ever; this occurred during the 1960s. Since the 2000s, the region has the highest nitrogen use efficiency at above 60 percent. It had moderate increases of synthetic fertilizers (from 3 kg per ha of cropland in the 1960s to 13 kg/ha in the 2010s) accompanied by similar levels of increases in crop uptake (from 9 kg/ha to 19 kg/ha). In 2018, the soil nutrient budget was 3.8 million tonnes distributed over cropland, with 45 percent of inputs attributed to synthetic fertilizers, 19 percent to atmospheric deposition, 19 percent to biological fixation, and 16 percent to manure applied to soils.

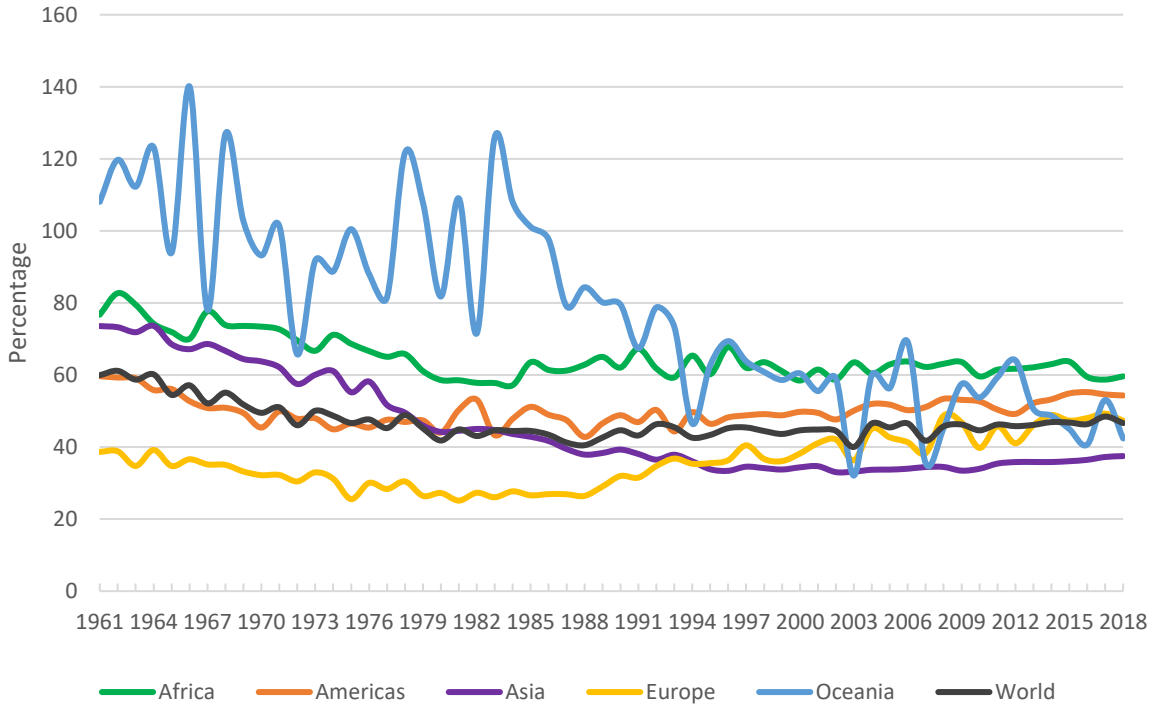
For Europe, a large proportion of total inputs come from manure applied to soils, and the region has maintained the highest application rate over the entire time period fluctuating around 30 kg per ha of cropland. Crop nitrogen uptake has outpaced increases in nitrogen inputs, and in the 2010s the region had a nitrogen use efficiency of 46 percent. 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 in the 1990s (-35 percent) and 2000s (-25 percent) in the soil nutrient budget. In 2018, the soil nutrient budget was 57 percent synthetic fertilizers, 5 percent biological fixation, 27 percent manure applied to soils, and 11 percent atmospheric deposition. In the 2010s, the region had 14 percent of global nitrogen inputs but over 17 percent of global nitrogen uptake from crops.

Figure 3: Global and regional soil nutrient budgets per cropland area, 1961–2018



Source: FAOSTAT Soil nutrient budget, 2021.

Figure 4: Global and regional nitrogen use efficiency, 1961–2018



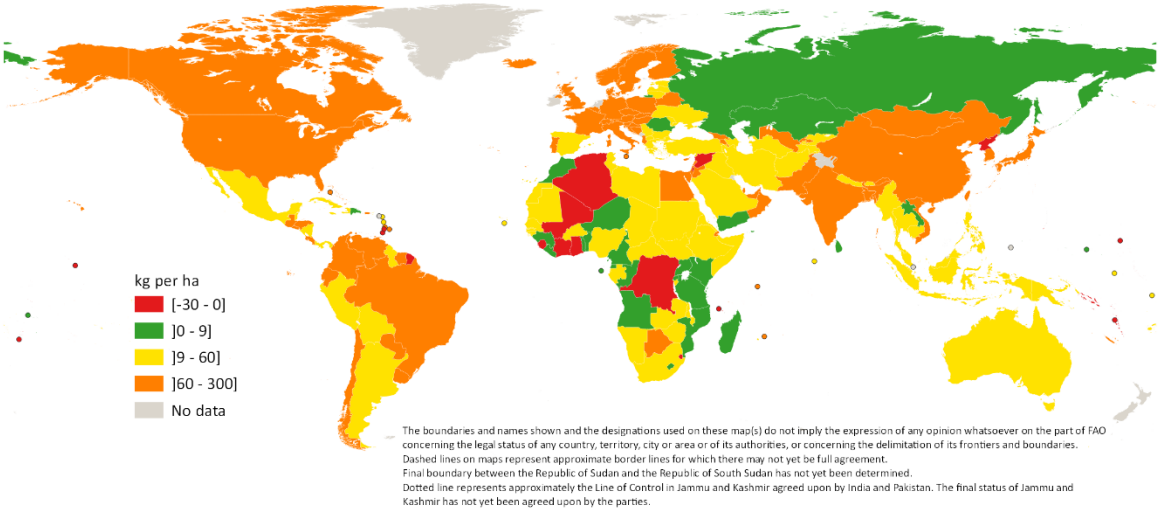
Source: FAOSTAT Soil nutrient budget, 2021.

Table 1: Global and regional inputs and outputs for soil nutrient budget per cropland area (kg/ha)

Region	1960s	1970s	1980s	1990s	2000s	2010s
Africa	**3**	**5**	**8**	**8**	**10**	**12**
Inputs (Total)	12	16	20	22	26	31
Synthetic fertilizers	3	6	10	10	11	13
Atmospheric deposition	4	5	5	6	6	7
Biological fixation	3	3	3	3	4	6
Manure applied to soils	2	2	3	4	4	5
Outputs - Crop uptake	9	11	12	14	16	19
Americas	**19**	**33**	**39**	**47**	**56**	**69**
Inputs (Total)	42	62	75	91	115	148
Synthetic fertilizers	17	31	38	44	51	63
Atmospheric deposition	6	6	7	8	8	8
Biological fixation	7	12	17	24	39	59
Manure applied to soils	12	12	13	15	16	17
Outputs - Crop uptake	23	29	36	44	58	78
Asia	**10**	**23**	**49**	**72**	**89**	**99**
Inputs (Total)	32	51	84	112	135	154
Synthetic fertilizers	9	24	53	76	94	109
Atmospheric deposition	8	10	12	14	15	16
Biological fixation	5	5	6	7	8	9
Manure applied to soils	10	12	13	16	18	20
Outputs - Crop uptake	22	28	35	40	46	56
Europe	**41**	**68**	**90**	**60**	**48**	**47**
Inputs (Total)	64	98	123	92	82	87
Synthetic fertilizers	26	54	74	49	45	50
Atmospheric deposition	7	7	8	9	10	10
Biological fixation	1	1	2	2	2	3
Manure applied to soils	30	35	38	32	26	25
Outputs - Crop uptake	23	29	33	33	35	40
Oceania	**-2**	**1**	**2**	**18**	**28**	**32**
Inputs (Total)	13	23	28	51	60	64
Synthetic fertilizers	4	11	16	37	46	50
Atmospheric deposition	2	2	2	3	3	3
Biological fixation	0	1	1	3	2	4
Manure applied to soils	7	10	8	9	9	7
Outputs - Crop uptake	15	22	26	34	31	32
World	**18**	**33**	**49**	**53**	**59**	**65**
Inputs (Total)	39	60	81	89	101	116
Synthetic fertilizers	14	30	47	52	59	69
Atmospheric deposition	6	8	9	10	11	11
Biological fixation	4	6	8	10	14	19
Manure applied to soils	14	16	17	17	17	17
Outputs - Crop uptake	21	26	32	35	42	51

Source: FAOSTAT Soil nutrient budget, 2021.

Map 1: Soil nutrient budgets per cropland area, 2018



Note: Red countries are classified as those with nutrient budgets per unit area of cropland less than 0. Green countries are classified as those with budgets between 0 and the median global nitrogen deposition rate over the entire time period. Yellow countries are classified as those with budgets greater than the median global nitrogen deposition rate but less than 60 kg/ha. Orange countries are those with nutrient budgets over cropland greater than 60 kg/ha.

Source: FAOSTAT Soil nutrient budget, 2021.

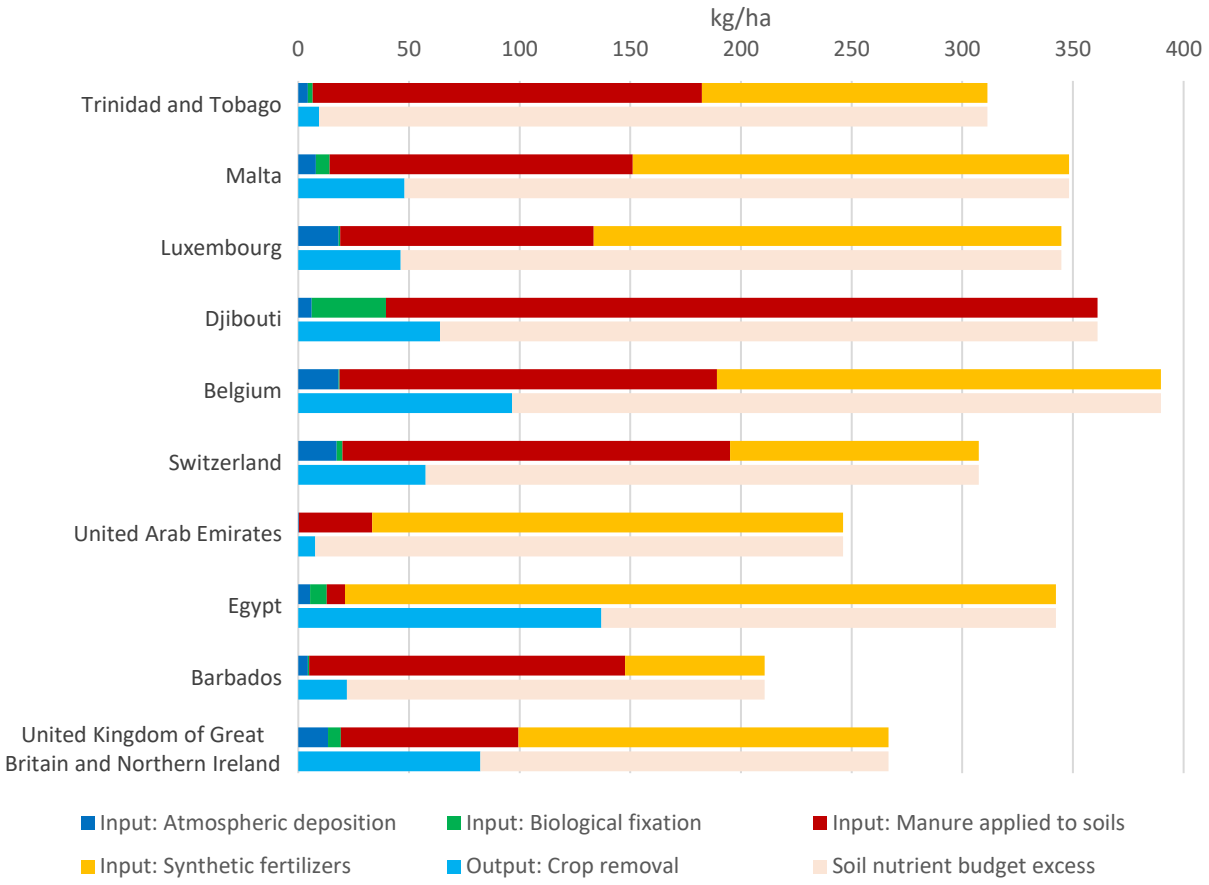
COUNTRY

The **top 10 countries** for the soil nutrient budget per unit area for the 2010s Trinidad and Tobago, Malta, Luxembourg, Djibouti, Belgium, Switzerland, the United Arab Emirates, Egypt, Barbados, and the United Kingdom of Great Britain and Northern Ireland. The soil nutrient budget among the top 10 countries during the 2010s ranged from 508 kg/ha in 2015 for Malta to 118 kg/ha in 2010 for Barbados, which is still 80 percent higher than the world average of 65 kg/ha. For some of these countries, such as Trinidad and Tobago, Malta, Luxembourg, Belgium, Switzerland, and Barbados, the high nutrient budget per unit area may be the result of limited cropland availability. For other countries in especially arid regions, such as Egypt, Djibouti, and the United Arab Emirates, low baseline soil quality may play a role in the high nutrient budgets (see Figure 5). In Egypt and the United Arab Emirates in particular, almost all the nutrient inputs come from synthetic fertilizers whereas Djibouti stands out with more than 85 percent of nutrient inputs coming from manure and close to 10 percent from biological fixation.

- Trinidad and Tobago had a soil nutrient budget per unit area of cropland of 322 kg/ha in 2018. The country applied synthetic fertilizers at a rate of 138 kg/ha, applied manure to soils at a rate of 185 kg/ha, and had biological fixation and atmospheric deposition at rates of 3.3 and 4.3 kg/ha, respectively. Nutrient removal from crops occurred at a rate of 9.3 kg/ha.
- Malta had a soil nutrient budget per unit area of cropland of 222 kg/ha in 2018. The country applied synthetic fertilizers at a rate of 125 kg/ha, applied manure to soils at a rate of 129 kg/ha, and had biological fixation and atmospheric deposition at rates of 6.1 and 8.0 kg/ha, respectively. Nutrient removal from crops occurred at a rate of 47 kg/ha.

- Luxembourg had a soil nutrient budget per unit area of cropland of 348 kg/ha in 2018. The country applied synthetic fertilizers at a rate of 205 kg/ha, applied manure to soils at a rate of 117 kg/ha, and had biological fixation and atmospheric deposition at rates of 0.9 and 18 kg/ha, respectively. Nutrient removal from crops occurred at a rate of 45 kg/ha.
- Djibouti had a soil nutrient budget per unit area of cropland of 288 kg/ha in 2018. The country applied manure to soils at a rate of 313 kg/ha, and had biological fixation and atmospheric deposition at rates of 34 and 6 kg/ha, respectively. Nutrient removal from crops occurred at a rate of 64 kg/ha.
- Belgium had a soil nutrient budget per unit area of cropland of 290 kg/ha in 2018. The country applied synthetic fertilizers at a rate of 195 kg/ha, applied manure to soils at a rate of 162 kg/ha, and had biological fixation and atmospheric deposition at rates of 0.5 and 18 kg/ha, respectively. Nutrient removal from crops occurred at a rate of 86 kg/ha.
- Switzerland had a soil nutrient budget per unit area of cropland of 241 kg/ha in 2018. The country applied synthetic fertilizers at a rate of 105 kg/ha, applied manure to soils at a rate of 173 kg/ha, and had biological fixation and atmospheric deposition at rates 3 and 17 kg/ha, respectively. Nutrient removal from crops occurred at a rate of 86 kg/ha.
- The United Arab Emirates had a soil nutrient budget per unit area of cropland of 212 kg/ha in 2018. The country applied synthetic fertilizers at a rate of 185 kg/ha, applied manure to soils at a rate of 37 kg/ha, and had atmospheric deposition at a rate of 0.2 kg/ha. Nutrient removal from crops occurred at a rate of 10 kg/ha.
- Egypt had a soil nutrient budget per unit area of cropland of 231 kg/ha in 2018. The country applied synthetic fertilizers at a rate of 342 kg/ha, applied manure to soils at a rate of 8 kg/ha, and had biological fixation and atmospheric deposition at rates 8 and 5 kg/ha, respectively. Nutrient removal from crops occurred at a rate of 133 kg/ha.
- Barbados had a soil nutrient budget per unit area of cropland of 180 kg/ha in 2018. The country applied synthetic fertilizers at a rate of 29 kg/ha, applied manure to soils at a rate of 171 kg/ha, and had biological fixation and atmospheric deposition at rates 0.5 and 4 kg/ha, respectively. Nutrient removal from crops occurred at a rate of 24 kg/ha.
- The United Kingdom of Great Britain and Northern Ireland had a soil nutrient budget per unit area of cropland of 192 kg/ha in 2018. The country applied synthetic fertilizers at a rate of 170 kg/ha, applied manure to soils at a rate of 83 kg/ha, and had biological fixation and atmospheric deposition at rates 6 and 13 kg/ha, respectively. Nutrient removal from crops occurred at a rate of 80 kg/ha.

Figure 5: Top 10 countries for soil nutrient budget per cropland area, 2010–2018



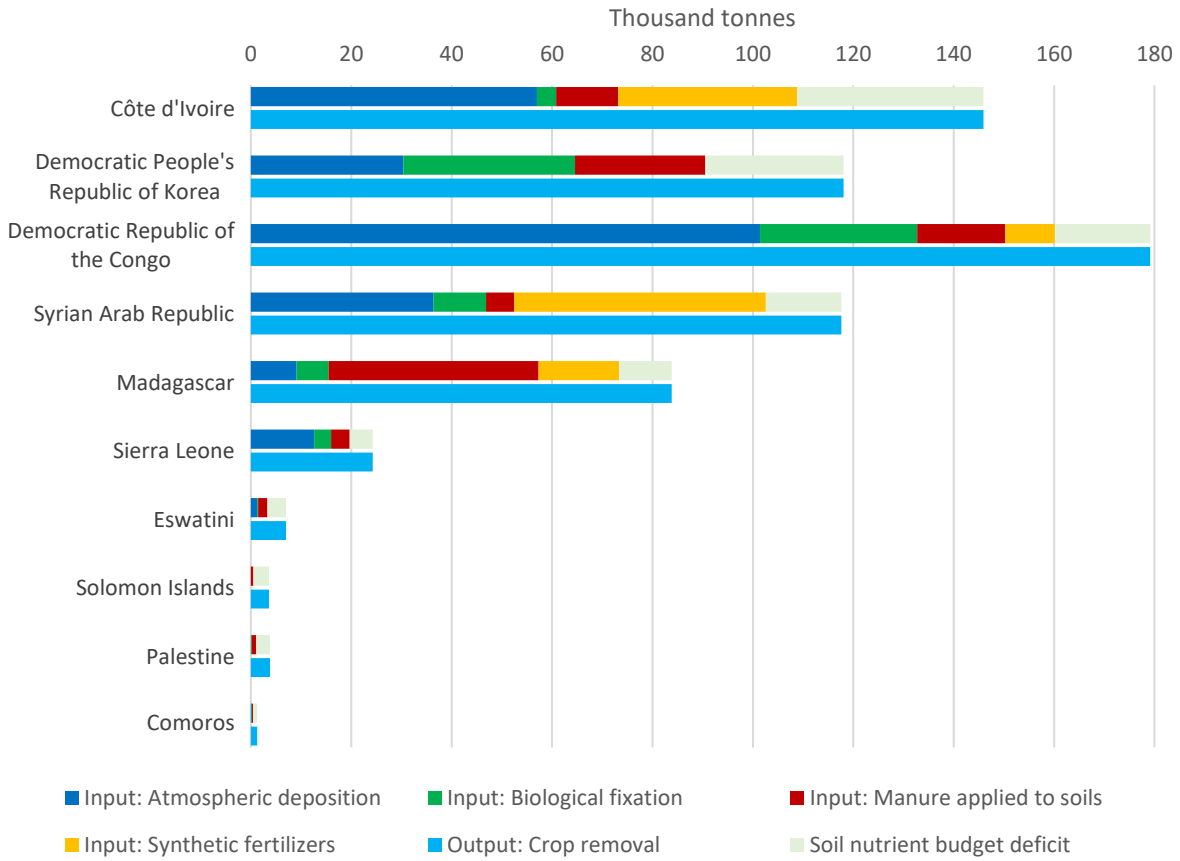
Source: FAOSTAT Soil nutrient budget, 2021.

The **bottom 10 countries** for the soil nutrient budget for the 2010s are Côte d'Ivoire, the Democratic People's Republic of Korea, the Democratic Republic of the Congo, the Syrian Arab Republic, Madagascar, Sierra Leone, Swaziland, the Solomon Islands, Palestine, and Comoros (see Figure 6). These countries all had negative nutrient budgets averaged over the 2010s, although Madagascar had a small positive nutrient budget in 2018. One half of the bottom 10 countries are in Africa.

- Côte d'Ivoire had a negative total nutrient budget over cropland in 2018 at -59 000 tonnes. Total inputs for this country were 109 000 tonnes and total crop removal was 167 000 tonnes.
- The Democratic People's Republic of Korea had a negative total nutrient budget over cropland in 2018 at -25 000 tonnes. Total inputs for this country were 78 000 tonnes and total crop removal was 102 000 tonnes.
- The Democratic Republic of the Congo had a small negative total nutrient budget over cropland in 2018 at -25 000 tonnes. Total inputs for this country were 166 000 tonnes and total crop removal was 191 000 tonnes.
- The Syrian Arab Republic had a small negative total nutrient budget over cropland in 2018 at -5 000 tonnes. Total inputs for this country were 56 000 tonnes and total crop removal was 61 000 tonnes.

- Madagascar had a small positive total nutrient budget over cropland in 2018 at 8 000 tonnes. Total inputs for this country were 89 000 tonnes and total crop removal was 82 000 tonnes.
- Sierra Leone had a small negative total nutrient budget over cropland in 2018 at -1 000 tonnes. Total inputs for this country were 18 000 tonnes and total crop removal was 19 000 tonnes.
- Swaziland had a small negative total nutrient budget over cropland in 2018 at -4 000 tonnes. Total inputs for this country were 3 000 tonnes and total crop removal was 7 000 tonnes.
- The Solomon Islands had a small negative total nutrient budget over cropland in 2018 at -3 000 tonnes. Total inputs for this country were 500 tonnes and total crop removal was 4 000 tonnes.
- Palestine had a small negative total nutrient budget over cropland in 2018 at -3 000 tonnes. Total inputs for this country were 1 000 tonnes and total crop removal was 4 000 tonnes.
- Comoros had very small negative total nutrient budget over cropland in 2018 at -900 tonnes. Total inputs for this country were 400 tonnes and total crop removal was 1 300 tonnes.

Figure 6: Bottom 10 countries for soil nutrient budget total, 2010–2018



Source: FAOSTAT Soil nutrient budget, 2021.

EXPLANATORY NOTES

- The FAOSTAT domain "Soil Nutrient Budget" disseminates nutrient flows in a given country and year. The soil nutrient budget can give an indication of nutrient use efficiency, as it can help quantify excess nitrogen leading to environmental risks, for instance, GHG emissions or pollution from volatilization and leaching/runoff. It can also signal soil nutrient deficits that limit crop production.
- The soil nutrient budget (SNB) is calculated as the sum of inputs: synthetic fertilizers (SF), manure applied to soils (MAS), nitrogen deposition (ND), and biological fixation (BF) minus outputs: crop removal (CR).
- Thus the SNB for country i for year y is calculated as:
  $SNB_{i,y} = sum(SF_{i,y}, MAS_{i,y}, ND_{i,y}, BF_{i,y}) – CR_{i,y}$
- Data for synthetic fertilizers are sourced from from the "Fertilizers by Nutrient" domain under "Inputs" in FAOSTAT for the element "Agricultural Use" and the item "Nutrient nitrogen N (total)". http://fenix.fao.org/faostat/internal/en/#data/RFN
- Data for manure applied to soils are sourced from the "Manure applied to Soils" domain under "Emissions – Agriculture" in FAOSTAT for the element "Manure (N content)" and aggregate item "All Animals + (Total)".
  http://fenix.fao.org/faostat/internal/en/#data/GU
- Nitrogen (N) deposition describes the input from the atmosphere of nitrogen to the soil as dry and wet deposition. Data were provided by the authors of the 2015 Nature publication "Managing nitrogen for sustainable development" (Nature 528, 51-59).
- For those countries with missing data, sub-regional deposition rates were applied.
- Crop removal was calculated from the "Crops" domain under "Production" in FAOSTAT using the coefficients from the International Plant Nutrition Institute (http://www.ipni.net/).
  http://www.fao.org/faostat/en/#data/QC
- The coefficients are listed in the metadata for the domain.
- Biological fixation was calculated from data from the "Crops" domain under "Production" in FAOSTAT and by applying the coefficients in the meta data of the domain to nitrogen-fixing plants.

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