FAOSTAT Domain Cropland Nutrient Budget Metadata, release November 2022

Dataset Information:

Title	**Cropland Nutrient Budget**
Abstract	The Cropland Nutrient Budget domain contains information on the flows of nitrogen, phosphorus, and potassium from synthetic fertilizer, manure applied to soils, atmospheric deposition, crop removal, and biological fixation over cropland and per unit area of cropland. The flows are aggregated to total inputs and total outputs, from which the overall nutrient budget and nutrient use efficiency on cropland are calculated. Statistics are disseminated in units of tonnes and in kg/ha, as appropriate. Nutrient use efficiency is expressed as a fraction (%). Data are available by country, with global coverage relative to the period 1961-2020, with annual updates.
Supplemental	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, i.e., it can help quantify excess nitrogen leading to environmental risks, for instance, greenhouse gas(GHG) emissions or pollution from volatilization and leaching/runoff. Alternatively, it can signal nutrient deficits that limit crop production.
Creation Date	2020
Last Update	2022
Data Type	Agri-Environmental
Category	Agriculture; Environment
Time Period	1961—2020
Periodicity	Annual
Geographical Coverage	World
Spatial Unit	The database covers 205 countries and territories
Language	Multilingual (EN, FR, ES)

Methodology and Quality Information:

Methods and processing

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).

Thus the NB for country *i* for nutrient *j* for year *y* is calculated as:

$$NB_{i,j,y} = sum(SF_{i,j,y} \times CF_{i,j,y}, MAS_{i,j,y}, ND_{i,j,y}, BF_{i,j,y}) - CR_{i,j,y}$$

The Nutrient Use Efficiency (NUE) for country i for nutrient j for year y is calculated as:

$$NUE_{i,j,y} = CRi_{,j,y}/sum(SF_{i,j,y} \times CF_{i,j,y}, MAS_{i,j,y}, ND_{i,j,y}, BF_{i,j,y})$$

The definition of cropland corresponds to that of FAOSTAT:
Cropland is land used for cultivation of crops, i.e. the total of areas under ''Arable land'' and ''Permanent crops'', where:
Arable land is the total of areas under temporary crops, temporary meadows and pastures, and land with temporary fallow. Arable land does not include land that is potentially cultivable but is not normally cultivated.

Land under temporary crops is land used for crops with a less-than-one-year growing cycle, which must be newly sown or planted for further production after the harvest. Some crops that remain in the field for more than one year may also be considered as temporary crops e.g., asparagus, strawberries, pineapples, bananas and sugar cane. Multiple-cropped areas are counted only once.
Land under temporary meadows and pastures is land temporarily cultivated with herbaceous forage crops for mowing or pasture. A period of less than five years is used to differentiate between temporary and permanent meadows and pastures.

Land with temporary fallow is land that is not seeded for one or more growing seasons. The maximum idle period is usually less than five years. This land may be in the form sown for the exclusive production of green manure. Land remaining fallow for too long may acquire characteristics requiring it to be reclassified, as for instance "Permanent meadows and pastures" if used for grazing or haying.

Land under permanent crops is land cultivated with long-term crops which do not have to be replanted for several years (such as cocoa and coffee), land under trees and shrubs producing flowers (such as roses and jasmine), and nurseries (except those for forest trees, which should be classified under "Forestry"). Permanent meadows and pastures are excluded from land under permanent crops.

Data for synthetic fertilizers for the Food and Agriculture Organization of the United Nations (FAO) are sourced from the "Fertilizers by Nutrient" domain under "Inputs" in FAOSTAT for the element "Agricultural Use" and the items "Nutrient nitrogen N (total)", "Nutrient phosphate P2O5 (total)", and "Nutrient potash K2O (total)".
https://www.fao.org/faostat/en/#data/RFN

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 Nitrogen (N), Phosphorus (P), and Potassium (K) using the mass percent composition conversions of 0.436 for P and 0.830 for K.

Below, in Table 1, fraction estimates for N and P for the years 1961, 1990, and 2020 are displayed. The cropland fraction estimates for Nitrogen were derived as follows:

The fractions for N were derived based on four existing datasets:

1. Fertilizer use by crop (FUBC) reports published in 2022 (Ludemann et al., 2022) and 2017 (Heffer and Roberts, 2017) by the IFA and collated by Ludemann et al., 2022,
2. Updated N fraction estimates to croplands from FAO for the countries of New Zealand and Ireland (FAO 2022),
3. Fraction estimates for European Countries from Einarsson et al. (2021), and,
4. Models of national nitrogen budgets for crop production compared in Zhang et al. (2021).

By comparing these existing datasets, 21 countries were identified where the fraction of N use for major crops is consistently lower than 100%.

Table 1: N and P cropland fraction estimates for 21 countries

Country	N	P	K
Australia	90%	70%	80%
Austria	90%	90%	90%
Brazil	90%	100%	95%
Canada	90%	100%	95%
Chile	80%	70%	75%
Finland	70%	100%	85%
France	90%	90%	90%
Germany	80%	90%	85%
Ireland	20%	30%	25%
Japan	80%	100%	90%
Morocco	90%	100%	95%
Netherlands	50%	90%	70%
New Zealand	10%	10%	10%
Poland	80%	90%	85%
Slovenia	60%	70%	65%
South Africa	90%	90%	90%
Switzerland	70%	70%	70%
United Kingdom of Great Britain and Northern Ireland	80%	70%	75%
United States of America	80%	100%	90%
Uruguay	90%	90%	90%
Luxembourg	40%	70%	55%

The cropland fraction estimates for Phosphorus were derived from:

Zou, T., Zhang, X. & Davidson, E.A. Global trends of cropland phosphorus use and sustainability challenges. Nature (2022). https://doi.org/10.1038/s41586-022-05220-z

Cropland fraction estimates for the nutrient K were calculated as the average of those for N and P. These fractions were applied to both synthetic fertilizer as well as manure applied to soils for the cropland nutrient budget. For countries not shown in Table 1, the fraction of N, P, and K applied to cropland is assumed to be 100%.

Data for manure applied to soils are sourced from the "Manure applied to Soils" domain under "Climate Change - Emissions – Farm gate" in FAOSTAT for the element "Manure (N content)" and aggregate item "All Animals + (Total)".
http://fenix.fao.org/faostat/internal/en/#data/GU

For the nutrients P and K, data for the N content of treated manure are extracted from the "Manure Management" domain under "Climate Change - Emissions – Farm gate" in FAOSTAT for the element "Manure treated (N content)" by livestock item. The N content is converted to P and K content using the unitless ratios shown in Table 2 below:

Table 2: Manure nutrient ratios for P and K by livestock category

Item Code	Item	P	K
960	Cattle, dairy	0.14	1.11
961	Cattle, non-dairy	0.19	0.95
976	Sheep	0.16	0.96
1016	Goats	0.17	0.88
1049	Swine, market	0.25	0.55
1051	Swine, breeding	0.28	0.45
1052	Chickens, layers	0.27	0.37
1053	Chickens, broilers	0.22	0.34
1068	Ducks	0.18	0.32
1079	Turkeys	0.23	0.33
1096	Horses	0.18	0.80
1759	Mules and Asses	0.18	0.80
1760	Camels and Llamas	0.18	0.80
946	Buffaloes	0.16	1.17

The unitless ratios were derived from nutrient excretion data reflected OECD countries (OECD Secretariat 1997), USA (Midwest Plan Service 1985) and Europe (Levington Agriculture 1997) and came from Sheldrick et al (2003). Data from Statistics Netherlands (2012) were used to fill in the gaps for some missing classes of livestock. Mules, Asses, Camels, and Llamas were assigned the same coefficients as Horses due to lack of data. As losses from manure management are more extensive for the nutrient Nitrogen, these conversion factors were applied to the manure treated.

References:

Sheldrick, W. et al. (2003) Soil nutrient audits for China to estimate nutrient balances and output/input relationships Agriculture, Ecosystems &Environment 94 (3) 341-354 https://doi.org/10.1016/S0167-8809(02)00038-5

Statistics Netherlands (2012) Standardised calculation methods for animal manure and nutrients: Standard data 1990-2008 The Hague, Netherlands pp 83 available at: https://www.cbs.nl/-/media/imported/documents/2012/26/2012-c173-pub.pdf

Nitrogen (N) deposition describes the input from the atmosphere of nitrogen to cropland as dry and wet deposition. Data were taken from the following public repository:
Vishwakarma, Srishti et al. (2022), Quantifying nitrogen deposition inputs to cropland: A national scale dataset from 1961 to 2020, Dryad, Dataset, https://doi.org/10.5061/dryad.msbcc2g1x

Specifically, the WL dataset was used as the reference dataset for N deposition in the global assessments of N budgets by countries. This data set uses N deposition maps from Wang, Q. et al. Data-driven estimates of global nitrous oxide emissions from croplands. Natl. Sci. Rev. 7, 441–452 (2020) in combination with cropland maps from Hurtt, G. C. et al. Harmonization of global land use change and management for the period 850-2100 (LUH2) for CMIP6. Geoscientific Model Development 13, (2020).

Crop removal was calculated from data for Primary Crops under the domain "Crops and livestock products" in FAOSTAT (https://www.fao.org/faostat/en/#data/QCL) using the coefficients in Table 4. Coefficients in Table 4 came from a meta-analysis of sources of data that purported to represent crop product nutrient coefficients at the world level. These data were taken from the following public repository:

Ludemann et al. (2022), Global data on crop nutrient concentration and harvest indices, Dryad, Dataset, https://doi.org/10.5061/dryad.n2z34tn0x.

Biological nitrogen fixation

Data on areas and harvests of nitrogen-fixing crops was taken from the domain "Crops and livestock products" in FAOSTAT, and biological nitrogen fixation (BNF) was calculated as follows.

For grain legumes, BNF was calculated using the yield-dependent and regionally specific model presented by Peoples et al. (2021) and Herridge et al. (2022).

Peoples, M.B., Giller, K.E., Jensen, E.S. et al. Quantifying country-to-global scale nitrogen fixation for grain legumes: I. Reliance on nitrogen fixation of soybean, groundnut and pulses. Plant Soil 469, 1–14 (2021). https://doi.org/10.1007/s11104-021-05167-6

Herridge, D.F., Giller, K.E., Jensen, E.S. et al. Quantifying country-to-global scale nitrogen fixation for grain legumes II. Coefficients, templates and estimates for soybean, groundnut and pulses. Plant Soil 474, 1–15 (2022). https://doi.org/10.1007/s11104-021-05166-7

For non-legume crops, BNF was calculated using the following fixed global per-hectare coefficients.

- Rice: 25 kg N per hectare harvested
  This coefficient is based on multiple lines of evidence. Smil (1999) suggested a fixation of 20-30 kg/ha/cropping season from free-living cyanobacteria, and 50-90 kg/ha/cropping season in rice fields with Azolla. Assuming 2% of rice fields having Azolla and 1.25 rice crops per year, these numbers lead to a total fixation of ca 33 kg N/ha/year, which is the estimate used by Herridge et al. (2008). However, since the FAOSTAT production data implicitly accounts for multi-cropping in its harvested areas, the factor 1.25 is not needed here. Moreover, as Ladha et al. (2022) characterize Azolla and legume green manures in rice as "negligible" and "insignificant" at present, Smil's estimate of 20-30 kg N/harvested ha from cyanobacteria appears as an appropriate coefficient. This is in line with the 22 kg N/ha fixation estimated based on crop N budgets by Ladha et al. (2016), and the 10-50 kg N/ha range reported by Ladha et al. (2022) based on 15N isotope methods.
- Sugar cane: 25 kg N per hectare harvested
  This coefficient was suggested by Herridge et al. (2008) based on consideration of multiple lines of evidence, and was also used by Zhang et al. (2021). The fixation in sugar cane is subject to a considerable uncertainty. Smil (1999) suggested that endophytic microbes in sugar cane fix at least 50 kg N/ha/year, maybe up to 150 kg N/ha/year or more. Such high rates have clearly been demonstrated on some fields using various methods (see, e.g., Herridge et al., 2008; Urquiaga et al., 2012; Baptista et al., 2014;

Martins et al., 2020) but were considered unlikely by Herridge et al. (2008) as an average. The coefficient 25 kg N/ha harvested used here is considered as a conservative estimate which may be revised upwards in the future.

References

Baptista, R. B., de Morais, R. F., Leite, J. M., Schultz, N., Alves, B. J. R., Boddey, R. M., & Urquiaga, S. (2014). Variations in the 15N natural abundance of plant-available N with soil depth: Their influence on estimates of contributions of biological N2 fixation to sugar cane. Applied Soil Ecology, 73, 124–129. https://doi.org/10.1016/j.apsoil.2013.08.008

Herridge, D. F., Peoples, M. B., & Boddey, R. M. (2008). Global inputs of biological nitrogen fixation in agricultural systems. Plant and Soil, 311(1–2), 1–18. https://doi.org/10.1007/s11104-008-9668-3

Ladha, J. K., Tirol-Padre, A., Reddy, C. K., Cassman, K. G., Verma, S., Powlson, D. S., van Kessel, C., de B. Richter, D., Chakraborty, D., & Pathak, H. (2016). Global nitrogen budgets in cereals: A 50-year assessment for maize, rice and wheat production systems. Scientific Reports, 6(1), 19355. https://doi.org/10.1038/srep19355

Ladha, J. K., Peoples, M. B., Reddy, P. M., Biswas, J. C., Bennett, A., Jat, M. L., & Krupnik, T. J. (2022). Biological nitrogen fixation and prospects for ecological intensification in cereal-based cropping systems. Field Crops Research, 283, 108541. https://doi.org/10.1016/j.fcr.2022.108541

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Smil, V. (1999). Nitrogen in crop production: An account of global flows. Global Biogeochemical Cycles, 13(2), 647–662. https://doi.org/10.1029/1999GB900015

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Zhang, X., Zou, T., Lassaletta, L., Mueller, N. D., Tubiello, F. N., Lisk, M. D., Lu, C., Conant, R. T., Dorich, C. D., Gerber, J., Tian, H., Bruulsema, T., Maaz, T. M., Nishina, K., Bodirsky, B. L., Popp, A., Bouwman, L., Beusen, A., Chang, J., … Davidson, E. A. (2021). Quantification of global and national nitrogen budgets for crop production. Nature Food, 2(7), 529–540. https://doi.org/10.1038/s43016-021-00318-5

A summary of the sources of data and coefficients for the domain can be found in Table 3, below.

Table 3: Sources of data for the items in the ESB domain

Synthetic fertilizers	Data	"Fertilizers by Nutrient" domain in FAOSTAT and IFASTAT http://fenix.fao.org/faostat/internal/en/#data/RFN https://www.ifastat.org/databases
	Coefficients	The cropland fraction estimates for Phosphorus were derived from: Zou, T., et. al. Global trends of cropland phosphorus use and sustainability challenges. Nature (2022).
Manure applied to soils	Data	"Manure applied to Soils" domain in FAOSTAT and http://fenix.fao.org/faostat/internal/en/#data/GU
	Nutrient Ratios	OECD Secretariat 1997, USA (Midwest Plan Service 1985) and Europe (Levington Agriculture 1997) and from Sheldrick et al (2003). Statistics Netherlands (2012).
Atmospheric Deposition	Data	Vishwakarma, Srishti et al. (2022), Quantifying nitrogen deposition inputs to cropland: A national scale dataset from 1961 to 2020, Dryad, Dataset. https://doi.org/10.5061/dryad.msbcc2g1x
Crop Removal	Data	Primary Crops under the domain "Crops and livestock products" https://www.fao.org/faostat/en/#data/QCL
	Coefficients	Ludemann et al. (2022), Global data on crop nutrient concentration and harvest indices, Dryad, Dataset. https://doi.org/10.5061/dryad.n2z34tn0x
Biological Fixation	Data	Primary Crops under the domain "Crops and livestock products" https://www.fao.org/faostat/en/#data/QCL
	Methods	Peoples et al. (2021) and Herridge et al. (2022).

Table 4: Nutrient Removal Coefficients at standard moisture content for each crop (kg Nutrient removed per tonne crop produced)

Item	N	P	K	Item	N	P	K
Almonds, with shell	38.9	10.9	70.5	Maize	12.4	3.4	4.3
Anise, badian, fennel, coriander	8.8	1.3	15.8	Maize, green	3.6	0.8	2.8
Apples	2.2	0.7	4.5	Mangoes, mangosteens, guavas	3.0	0.6	3.8
Apricots	3.7	0.7	2.2	Manila fibre (abaca)	2.9	1.1	3.3
Areca nuts	7.8			Melonseed	29.1		
Artichokes	3.2			Millet	20.4	4.2	5.4
Asparagus	4.8	0.9	4.2	Mushrooms and truffles	9.3		
Avocados	2.7	0.9		Mustard seed	39.8		
Bambara beans	25.7	5.1	15.3	Nutmeg, mace and cardamoms	13.1	1.3	15.8
Bananas	1.4	0.4	8.9	Nuts nes	11.2		
Barley	18.0	3.2	5.8	Oats	21.6	3.6	4.5
Bastfibres, other	4.3	1.1	3.3	Oil palm fruit	3.6	0.7	4.1
Beans, dry	41.8	5.7	19.5	Oilseeds nes	13.1	4.6	21.7
Beans, green	4.1	0.7	2.2	Okra	2.8	0.5	3.0
Berries nes	1.6			Olives	7.3	11.3	10.0
Blueberries	1.1	0.0	0.8	Onions, dry	2.6	0.7	2.2
Brazil nuts, with shell	11.0			Onions, shallots, green	2.6	0.5	1.8
Broad beans, horse beans, dry	30.2	5.1	15.3	Oranges	3.1	0.4	4.6
Buckwheat	17.3	2.2	3.7	Papayas	59.8	17.9	144.4
Cabbages and other brassicas	3.8	0.4	3.0	Peaches and nectarines	2.2	0.4	3.3
Canary seed	20.3	2.9	10.8	Pears	1.8	0.4	2.6
Carobs	2.6			Peas, dry	38.0	8.7	9.8
Carrots and turnips	2.1	0.5	2.3	Peas, green	16.7	3.3	10.0
Cashew nuts, with shell	12.3			Pepper (piper spp.)	9.8	1.3	15.8
Cashewapple	1.3			Peppermint	11.5	1.3	15.8
Cassava	2.7	3.3	2.6	Persimmons	1.0		
Castor oil seed	14.4			Pigeon peas			
Cauliflowers and broccoli	4.0	0.9	3.2	Pineapples	1.0	0.2	1.4
Cereals nes	14.5	2.9	4.4	Pistachios	16.5		
Cherries	1.8			Plantains and others	3.3	0.3	5.0
Cherries, sour	1.4			Plums and sloes	2.4		
Chestnut	2.9			Poppy seed	28.8		
Chick peas	27.6	5.1	15.3	Potatoes	2.5	1.0	6.2
Chicory roots	1.8			Pulses nes	26.1	4.2	13.2
Chillies and peppers, dry	11.7	1.2	9.5	Pumpkins, squash and gourds	2.7	0.4	3.2
Chillies and peppers, green	2.2	0.5	2.2	Pyrethrum, dried	13.5	1.3	15.8
Cinnamon (cannella)	11.6	1.3	15.8	Quinces	0.3		
Cloves	18.9	4.0	17.8	Quinoa	19.2		
Cocoa, beans	23.2	6.0	35.7	Ramie	4.0	1.1	3.3
Coconuts	19.1	3.8	6.6	Rapeseed	31.4	5.9	
Coffee, green	23.2	3.5	17.5	Raspberries	1.4		
Cow peas, dry	30.2	5.1	15.3	Rice, paddy	12.9	2.8	3.0
Cranberries	0.6			Roots and tubers nes	4.4	0.3	2.9
Cucumbers and gherkins	1.5	0.5	1.6	Rubber, natural	7.2	1.3	4.4
Currants	2.2			Rye	21.3	3.6	4.6
Dates	2.4			Safflower seed	30.1	5.4	19.2
Eggplants (aubergines)	2.8	0.8	2.9	Seed cotton	55.8	11.3	31.5
Fibre crops nes	4.3	1.1	3.3	Sesame seed	25.7	5.1	9.7
Figs	3.0			Sisal	5.0	1.1	3.3
Flax fibre and tow	13.8	3.5	6.4	Sorghum	14.6	4.5	4.2
Fonio	12.8	2.2	4.2	Soybeans	59.3	8.1	18.3
Fruit, citrus nes	1.5	0.3	2.4	Spices nes	12.7	1.0	8.8
Fruit, fresh nes	1.9	0.4	2.0	Spinach	4.0	0.6	3.7
Fruit, pome nes	3.0	0.7	2.0	Strawberries	5.5	1.7	8.3
Fruit, stone nes	2.2	0.7	2.0	String beans	3.0	0.7	2.2
Fruit, tropical fresh nes	2.8	0.7	2.0	Sugar beet	2.1	0.5	2.3
Garlic	6.4	0.9	2.7	Sugar cane	4.7	0.3	1.3
Ginger	15.8	1.3	15.8	Sugar crops nes	0.0		
Gooseberries	1.4			Sunflower seed	23.6	3.9	6.5
Grapefruit (inc. pomelos)	1.8			Sweet potatoes	3.4	0.8	6.9
Grapes	3.6	0.7	5.4	Tallowtree seed			
Groundnuts, with shell	33.6	6.0	8.2	Tangerines, mandarins, clementines, satsumas	1.9	0.4	1.3
Gums, natural	147.5			Taro (cocoyam)	3.7	1.1	3.3
Hazelnuts, with shell	5.3	0.4	1.7	Tea	18.8	2.6	14.6
Hemp tow waste	3.1	1.1	3.3	Tobacco, unmanufactured	41.8	6.6	47.7
Hempseed	35.2			Tomatoes	1.4	0.2	2.4
Hops	18.5	1.3	15.8	Triticale	17.3	2.9	4.2
Jojoba seed				Tung nuts	48.0		
Jute	2.7	1.1	3.3	Vanilla	8.5	1.3	15.8
Karite nuts (sheanuts)	10.9			Vegetables, fresh nes	5.6	0.9	2.6
Kiwi fruit	1.4			Vegetables, leguminous nes	4.9	1.1	3.3
Kola nuts	14.4			Vetches	33.5	4.0	17.4
Leeks, other alliaceous vegetables	3.1	0.9	2.7	Walnuts, with shell	22.1	4.4	10.0
Lemons and limes	1.8			Watermelons	1.8		
Lentils	35.9	4.4	15.8	Wheat	20.9	4.2	5.2
Lettuce and chicory	2.4	0.4	2.9	Yams	2.1		
Linseed	28.8			Yautia (cocoyam)	3.9	1.1	3.3
Lupins	43.5	5.1	15.3				

FAOSTAT Domain Cropland Nutrient Budget Metadata, release November 2022

Data Collection Method	Computed
Data Quality	Data quality for the questionnaire-based domains (Crop Production and Fertilizers) is driven from their FAOSTAT processes. Data for the other inputs are calculated. The domain has coverage for 205 countries and territories.
Useful links	https://www.fao.org/faostat/en/#data/QCL https://www.ifastat.org/databases/plant-nutrition http://fenix.fao.org/faostat/internal/en/#data/GU

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Citation	FAO, 2022. FAOSTAT and IFA Cropland Nutrient Budget database http://www.fao.org/faostat/en/#data/ESB
Acknowledgements	The FAOSTAT Cropland Nutrients database is developed and maintained by FAO Statistics Division (ESS) with Regular Programme Funding. This is part of an ongoing collaboration with the International Fertilizer Association (IFA), which provides fertilizer statistics through IFASTAT within the scope allowed by its confidentiality obligations. The 2022 update was performed thanks to the following contributors: FAO: Francesco Tubiello, Nathan Wanner, Griffiths Oblilaryea, Xueyao Pan International Fertilizer Association (IFA): Achim Dobermann, Armelle Gruere, Patrick Heffer University of Maryland Center for Env. Science: Xin Zhang, Srishti Vishwakarma, Kevin Jackson Wageningen University & Research: Cameron Ludemann, Martin van Ittersum Swedish University of Agricultural Sciences: Rasmus Einarsson Universidad Politécnica de Madrid: Luis Lassaletta African Plant Nutrition Institute: Pauline Chivenge University of Nebraska-Lincoln: Patricio Grassini