SANH POLICY BRIEF

SYNTHETIC NITROGEN FERTILISER IN SOUTH ASIA: PRODUCTION, IMPORT, EXPORT AND USE FOR CROPS

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KEY FINDINGS

1. Synthetic nitrogen (N) fertilisers are critical for global food production. South Asia region (SAR), has amongst other regions, the highest fertiliser use growth rates, but nitrogen use efficiency has been decreasing, leading to increased waste of reactive nitrogen (N_r) resources.

2. Waste of N_r impacts human and environmental health, via emissions to the air, leaching or, run-off, and other forms of pollution.

3. In SAR, nitrous oxide (N_2O), a major greenhouse gas (GHG), rose by 49% between 2000 and 2018. Ammonia (NH_3), a major air pollutant that contributes to fine particulate matter ($PM_{2.5}$), rose by 42%.

4. Agriculture is increasing as a major N_r emission source. In SAR, the agriculture sector contributed to 78% of overall emissions of N_2O, and 86% of all emissions of NH_3.

5. India, Pakistan and Bangladesh together account for 99% of the SAR synthetic fertiliser emissions for NH_3 and N_2O in 2018, consistent with statistics on fertiliser production and import.

6. Urea, the most commonly used fertiliser product, and a major contributor to N_r emissions, accounts for 80% of all synthetic fertiliser use in SAR. India, Pakistan and Bangladesh accounted for 98% of urea use and 99% of DAP[1] use in SAR in 2020.

7. India, Pakistan, Bangladesh and Afghanistan are current/recent producers, of synthetic N_r fertiliser[2]. Sri Lanka and Nepal were producers in the 1980s.

8. All eight SAR countries import synthetic N fertiliser.

9. Only three countries export synthetic N fertiliser. The biggest exporter was India (1,640 kilotons (kt)), followed by Sri Lanka (0.06 kt) and then Pakistan (0.04 kt) in 2020. .

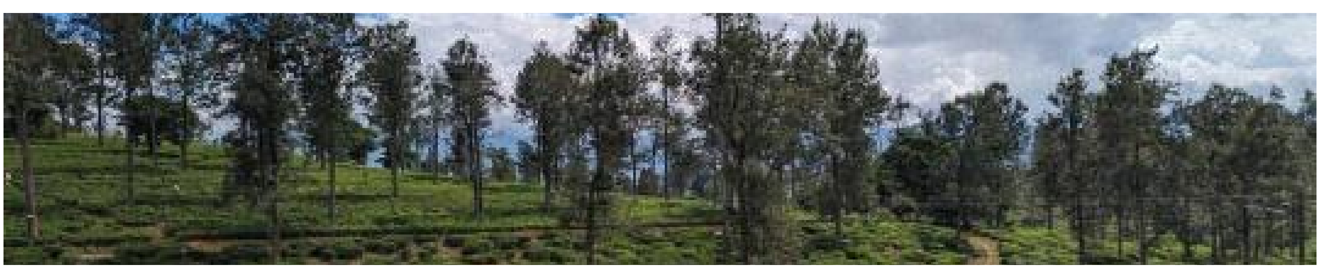
10. In 2020, synthetic fertiliser use per capita was highest for Pakistan (16 kg) followed by India (15 kg), Sri Lanka (11 kg), Bangladesh (8 kg), and Nepal (5 kg) in 2020. N use per hectare cropland was highest for Bangladesh (146 kg), followed by India (121 kg) and then Pakistan (111 kg) in 2020. N use per cropland area has increased over time for seven of the SAR countries.

11. Crop production has been increasing across 7 out of the 8 SAR countries, except the Maldives, where food imports have become more important.

12. Fertilizer and related policies across SAR likely influence how fertiliser is accessed, traded and used, and therefore directly and indirectly impacting N_r pollution. This requires further investigation.

13. Based on current N_r emission trends, including the GHG N_2O, are set to rise unless ambitious policy actions and measures are implemented.

14. Actions to increase nitrogen use efficiency (NUE) across agriculture are a priority to introduce more sustainable N management across SAR.



[1] Di-ammonium phosphate (DAP)

[2] According to FAOSTAT data in the year 2020

Cover page photo: Farmer, Nepal; Photo by S.P Pradhan)
Page 1 Photo: Tea Plantation, Sri Lanka. Photo by A.. Yang

SOUTH ASIA NITROGEN HUB (SANH)

This policy brief is produced by the UKRI GCRF South Asian Nitrogen Hub (SANH). It provides an overview of the patterns and trends in synthetic nitrogen (N) fertiliser use in crop production, import, export and emission in the South Asian Region (SAR) and its member countries; Afghanistan, Bangladesh, Bhutan, Nepal, India, Maldives, Pakistan, and Sri Lanka. In summary, reactive nitrogen (Nr) in fertilisers is essential for meeting global food and animal feed demands, but Nr pollution has become a major environmental issue across all scales. For SAR, inefficient use of synthetic N fertiliser is a key factor contributing to water pollution, air pollution, climate change, biodiversity loss and soil degradation. Further insights are provided on major fertiliser products, as well as in crop production, import and export. These data are essential for informing and promoting sustainable nitrogen management.

Evidence based policy is more important than ever. The SANH is supported by UK Research and Innovation (UKRI) through its Global Challenge Research Fund (GCRF) to gather evidence on nitrogen issues to support countries in the South Asian Region (SAR) comprising eight countries (Nepal, Bangladesh, Pakistan, India, Bhutan, Sri Lanka, Afghanistan, and Maldives) to identify solutions and reduce nitrogen waste. SANH is pioneering a UK-SAR research partnership to catalyse transformational change in SAR to tackle the nitrogen challenge, benefiting the economy, people's health and the environment. SANH brings together 32 leading research organisations with governments and other partners. This policy brief provides key insights into national fertiliser trends for all eight SAR countries.

1. NITROGEN ISSUE IN A NUTSHELL

Unlike carbon dioxide (CO_2), nitrogen has much lower public awareness as a pressing environmental problem. Yet reactive nitrogen (N_r) emissions have more than doubled since the 1970's,[3] presenting a significant issue globally and regionally for SAR. Unreactive di-nitrogen (N_2), a natural component of the atmosphere, is transformed to N_r via human interventions (e.g., Haber-Bosch process and increased biological nitrogen fixation), due to its benefits for agriculture and industry. The production of N_r for fertiliser has been critical for sustaining food demands as the global population grows (Mosier et al., 2004). Yet nitrogen waste has widespread negative impacts on human health and the environment.[4] For example, N_r contributes to the formation of particulate matter ($PM_{2.5}$)[5] and therefore air pollution, which is a leading cause of death in SAR (HEI, 2020). In a recent report on air pollution in SAR by the World Bank (2022a), $PM_{2.5}$ is estimated to cause over 2 million premature deaths each year. Nitrogen pollution not only affects air quality, but also impacts water quality through eutrophication, contributes to greenhouse gas (GHG) emissions, and impacts ecosystem and soil health (Sutton et al., 2013). The SAR, including Nepal, Bangladesh, Pakistan, India, Bhutan, Sri Lanka, Afghanistan, and Maldives, is a global hotspot for N_r emissions (SACEP-SANH, 2022).

Ammonia (NH_3), a major air pollutant that contributes to fine particle ($PM_{2.5}$) and threatens the biodiversity of natural ecosystems, rose by 42%, and nitrous oxide (N_2O) rose by 49% between 2000 and 2018 (EDGAR v6.1). Emissions from nitrogen oxides (NO_x) are a major issue in SAR due to both the amount of emissions being released and the rate of increase (95% between 2000 and 2018) (EDGAR v7.0[6]) N_2O, as a GHG, has 310 times higher global warming potential than CO_2 over 100 year period (IPCC/TEAP, 2005; Forster et al., 2007).. Careful management of nitrogen is therefore an essential component of the wider sustainable development agenda (Chang et al., 2021). Reducing excess N_r is crucial to address many of the environmental crises the world currently faces.

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[3] 100 Teragram (Tg) N yr^{-1} in 1970 to nearly 210 Tg N yr^{-1} in 2010 (Malik et al., 2022).

[4] Nitrogen waste has been defined by the UN Economic Commission for Europe (UNECE) as "the sum of all nitrogen losses to the environment (including N_2 and all N_r forms)" adding "Although emission of gaseous N_2 does not lead directly to adverse environmental effects, its release can be considered as a waste of the energy used to produce N_r, as well as a lost resource of useful nitrogen, indicating the need for N_2 emissions to also be addressed" (Sutton et al.,2022, paras.113, 78).

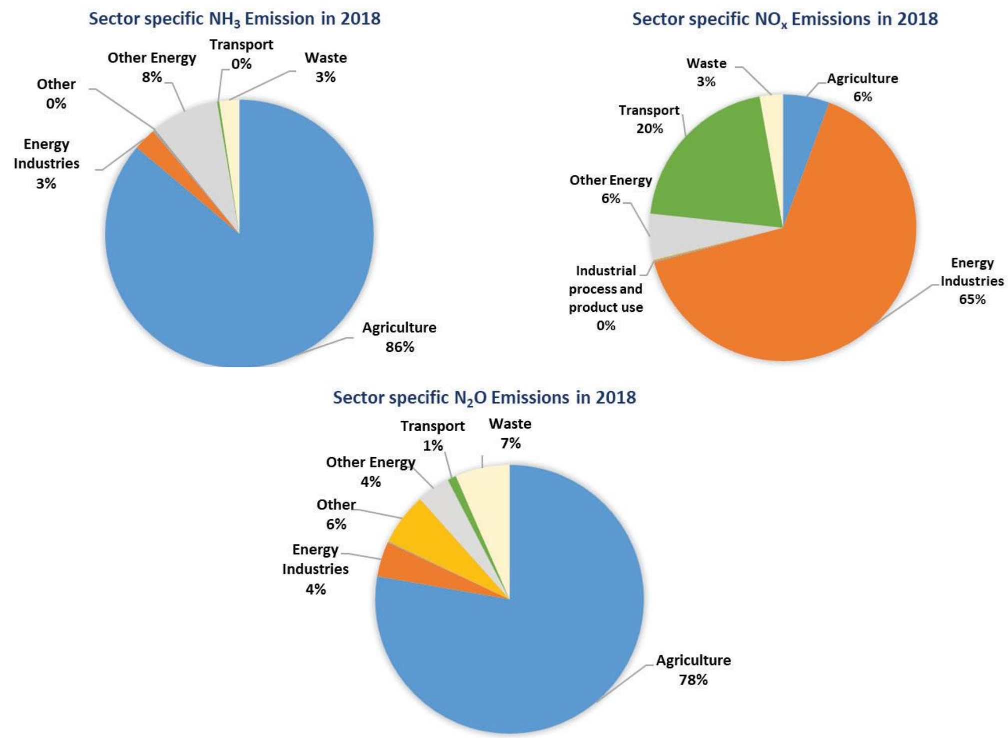
[5] Nitrogen oxides (N_2O) and ammonia (NH_3) are precursors of $PM_{2.5}$ and affect the chemical reactions that lead to $PM_{2.5}$ formation (Gu et al., 2021). Gu et al. calculated that NH_3 emissions globally contributed to 32% $PM_{2.5}$ pollution in 2013, and N_2O emission to 28%. Rises in NH_3 and N_2O were linked to global increases in deaths caused by $PM_{2.5}$.

[6] In this briefing, all N emission data are sourced from the Emissions Database for Global Atmospheric Research (EDGAR), to ensure data reliability, consistency and compatibility for each country in South Asia https://edgar.jrc.ec.europa.eu/emissions_data_and_maps provides independent emission estimates, using international statistics and a consistent Intergovernmental Panel on Climate Change (IPCC) methodology. A refinement of the EDGAR estimates for South Asia is in preparation as part of SANH.

2. AGRICULTURE & NITROGEN

Agriculture is a huge contributor to N_r emissions. Ammonia (NH_3) and nitrous oxide (N_2O) are key polluting compounds emitted from agricultural livestock farming and fertiliser use. In SAR, agriculture has been steadily increasing as a major N_r emission source, contributing 78% to overall emissions of N_2O and 86% of all NH_3 emissions in 2018, as seen in Figure 1 (EDGAR v6.1). For NO_x emissions, agriculture is estimated to be a modest contributor (at 6%), compared to NH_3 and N_2O, with the energy sector contributing the largest share (65%).

Figure 1. Estimated percentage of sector specific reactive nitrogen emissions: nitrous oxide (N_2O), ammonia (NH_3), and nitrogen oxides (NO_x) in South Asia in 2018. This figure is derived from datasets reported by Crippa et al. 2021a; EDGARv6.1 air pollutants and GHG.



3. SYNTHETIC FERTILISERS & NITROGEN

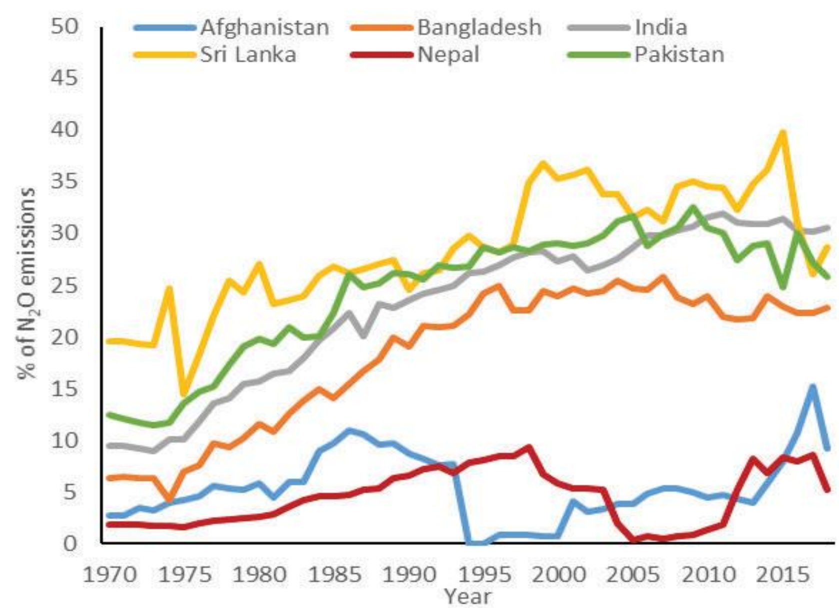
The production of N_r for use as fertiliser has been critical for sustainable food production as the global population is growing (Mosier et al. 2004), providing vital nutrients. Synthetic fertiliser (chemically manufactured) and organic (derived from plants and/or animal manures) are the two main fertiliser types. This briefing focuses on 'new' nitrogen fertiliser, also known as synthetic fertiliser. SAR has some of the highest growth rates in synthetic fertiliser use globally, at 50% between 2002 and 2017 (FAO, 2020; SACEP-SANH, 2022). But, as fertiliser use has increased, nitrogen use efficiency (NUE) has been decreasing. In India, for example, NUE reduced from 55% to 35% between 1960 and 2010 (Bijay, 2017; Lassaletta et al., 2014; Moring et al., 2021). By contrast, it was reported that in Bangladesh, the total N input per unit of cropland area was 40% higher than in India and Pakistan in 2018, however, NUE was estimated to be higher at 48% (Bijay et al., 2022). The NUE of our global food system is estimated to be as low as 15% (Sutton et al., 2013; Sutton et al., 2017).

From production to use, synthetic fertilisers are a key source of N_r pollution and other greenhouse gas (GHG) emissions (Walling and Vaneeckhaute, 2020). Emissions can be released due to the efficiency and operating conditions, amongst other factors, during fertiliser (synthetic and organic) production, storage, transportation, and use (Walling and Vaneeckhaute, 2020). Synthetic nitrogen fertiliser production, mainly through the Haber-Bosch process, has high energy demands. It is one of globe's largest energy consumers and GHG emitters, which is mainly powered by fossil fuels (Ghavam et al., 2021). Approximately 2% of the world's energy use reportedly goes into synthetic N fertiliser production (Sutton et al., 2013), which explains why fertiliser prices are closely coupled with global energy prices.

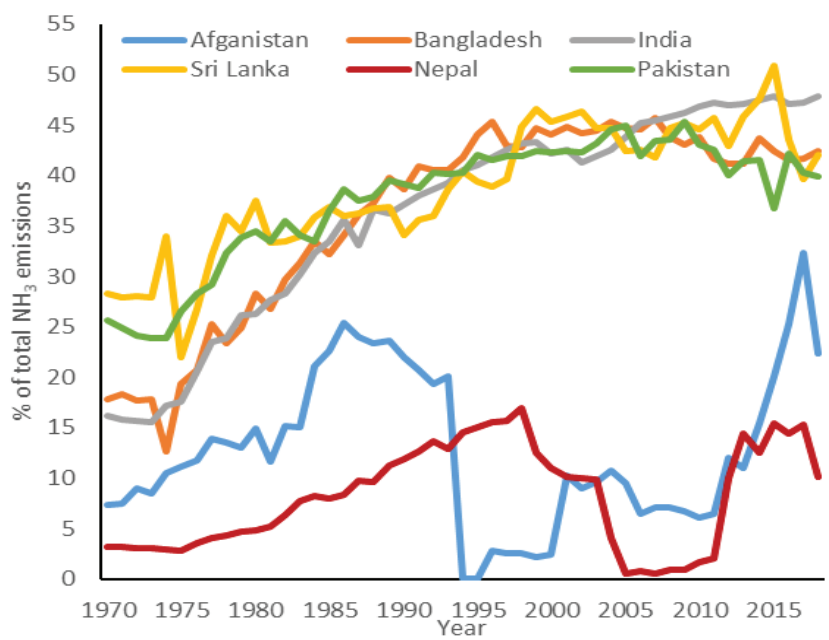
Synthetic fertilisers contribute almost half (~50%) of the total NH_3 emissions for Sri Lanka, Pakistan, India, and Bangladesh (see Figure 2). For Nepal and Afghanistan these contributions have varied, but increased between 2012 and 2017. Sri Lanka has the highest average contribution of synthetic fertilisers to N2O emissions, peaking in 2015 at 40%. For SAR, synthetic fertiliser generated 53% of NH_3 emissions and 37% of overall N_2O emissions from agriculture in 2018. These numbers underscore the need for sustainable management of synthetic fertilisers in agriculture to address regional NH_3 and N_2O emissions. Synthetic fertiliser emission estimates for Maldives and Bhutan are not reported by EDGAR (See Box 1).

Figure 2. Estimated percentage share of a) ammonia (NH_3) emissions and b) Nitrous oxide (N_2O) emissions from synthetic fertilisers (urea and other) from the total emissions for each gas in South Asian countries 1970-2018. This figure is derived here from datasets reported by Crippa et al. 2021a; EDGARv6.1 air pollutants and GHG. Synthetic fertiliser emission estimates for Maldives and Bhutan are not reported by EDGAR

a) Ammonia (NH_3)



b) Nitrous oxide (N_2O)



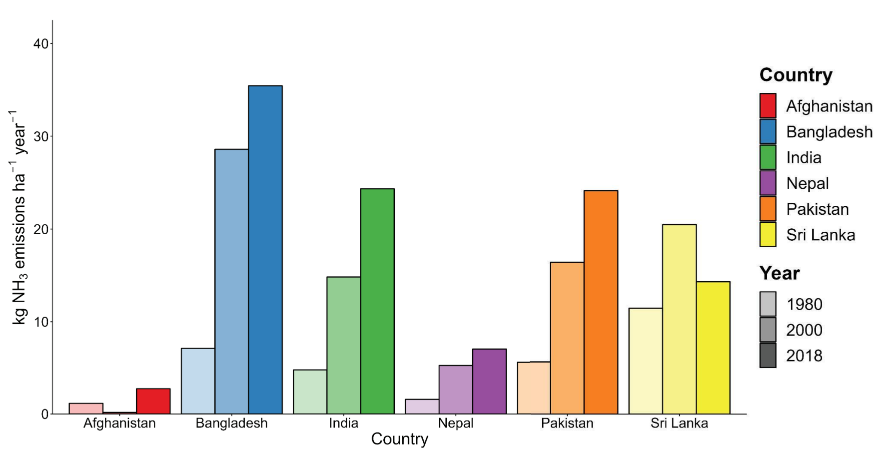
Box 1. Emission estimates for Bhutan and Maldives

Emission data for N_2O and NH_3 are available for Bhutan and Maldives from EDGAR ver.6.1 and 7.0. However EDGAR has not reported synthetic fertiliser emission estimates for Bhutan and Maldives, likely due to the negligible amounts of synthetic fertiliser used and/or reported. N_2O synthetic fertiliser emission data is provided by FAOSTAT for the two countries. Yet as different estimation methods are used by EDGAR and FAOSTAT the statistics are not comparable, these statistics are therefore reported separately here. The FAOSTAT estimations for N_2O indicate relatively small emission amounts, for example, synthetic fertiliser N_2O emissions in Bhutan are 0.03 kiloton (kt) and 0.01 kt for Maldives in 2018 (FAOSTAT,2023). The per capita N_2O emissions for Bhutan are 24kg and for Maldives 60 kg in 2018. The N_2O emissions per hectare of cropland for Bhutan are 3kg and Maldives 0.6kg.

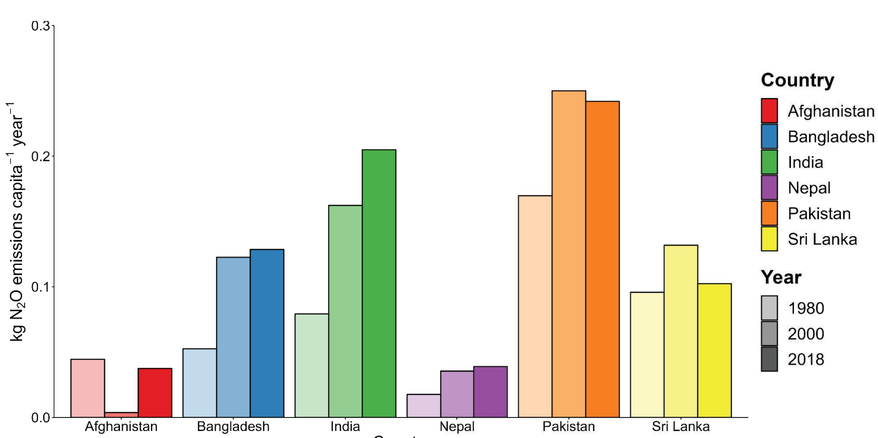
One of the key messages of Figure 2 is that around 99% of the synthetic fertiliser emissions of NH_3 and N_2O in SAR derive from just three countries. For NH_3 and N_2O this is India (78%), Pakistan (15%) and Bangladesh (6%) (values for 2018)[7]. Comparisons can however be made on a per hectare (ha) and per capita basis as seen in Figure 3 and 4. By standardising NH_3 and N_2O emissions against crop area (ha) and per capita it can be seen that Pakistan has amongst the highest emissions per capita, and Bangladesh for per unit of cropland. Emission patterns per capita and per crop area indicate increases from 1980, 2020, to 2018 for Nepal, Bangladesh, India and Pakistan. Whereas emissions for Afghanistan dropped in 2000 then increased by 2018, and emissions for Sri Lanka dropped from 2000 to 2018. See additional information Section A. for N_r emission tables.

Figure 3. Estimated ammonia (NH_3) emissions for each country in South Asia in 1980, 2000 and 2018: a) kg NH_3 per capita b) per cropland hectare. This figure is derived from datasets reported by Crippa et al. 2021a; EDGARv6.1 air pollutants. Synthetic fertiliser emission estimates for Maldives and Bhutan are not reported by EDGAR.

a) Ammonia (NH_3) emissions (kg) per capita



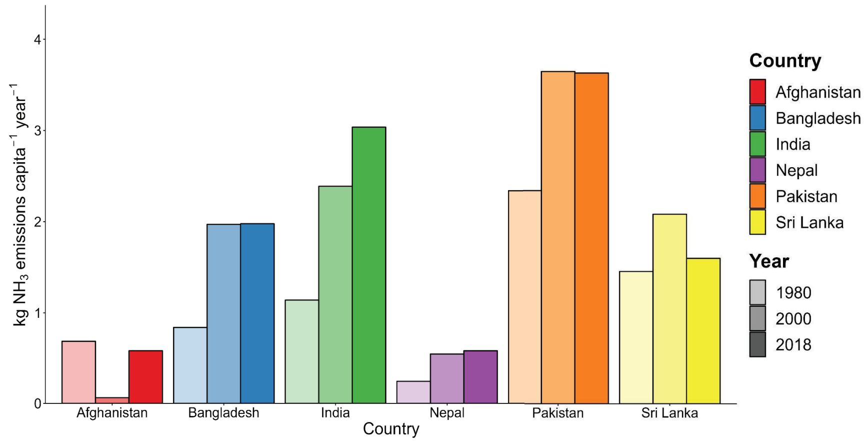
b) Ammonia (NH_3) emissions (kg) cropland (per ha)



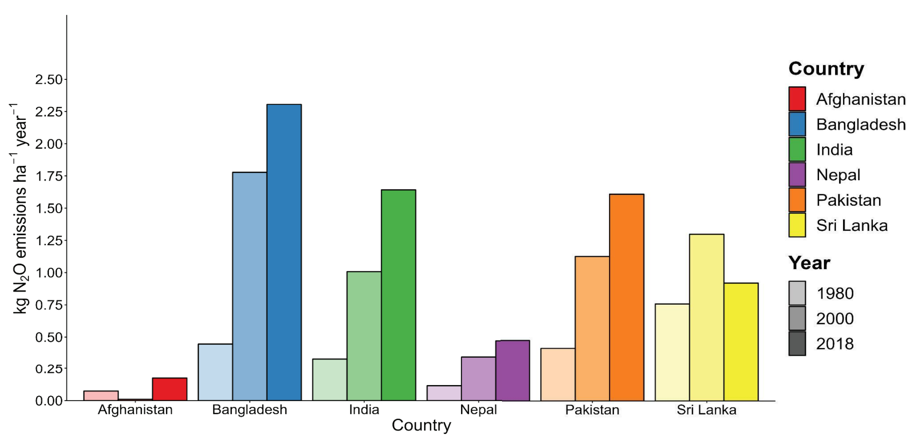
[10] These estimates include India, Pakistan, Sri Lanka, Afghanistan, Bangladesh, and Nepal. EDGAR data v6.1 and 7.0 on synthetic N_20 and NH_3 emissions for Maldives and Nepal are unavailable.

Figure 4. Estimated ammonia (N_2O) emissions for each country in South Asia in 1980, 2000 and 2018: a) kg N_2O per capita b) kg N_2O per cropland hectare. This figure is derived from datasets reported by Crippa et al. 2021a; EDGARv6.1 GHG. Synthetic fertiliser emission estimates for Maldives and Bhutan are not reported by EDGAR.

a) Nitrous oxide (N_2O) emissions (kg) per capita



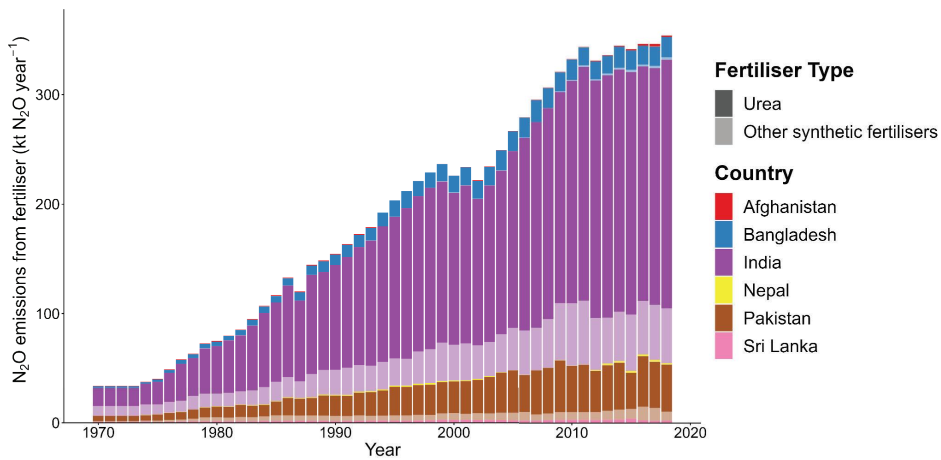
b) Nitrous oxide (N2O) emissions (kg cropland (per ha)



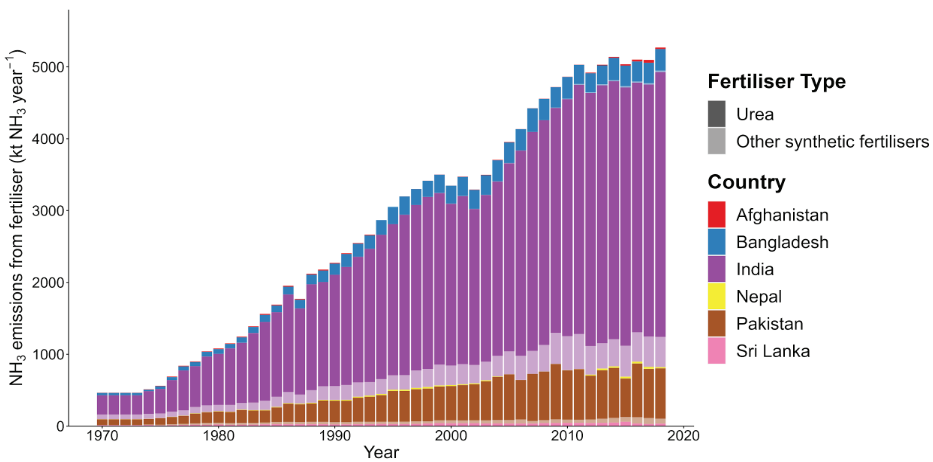
Urea is the most commonly used nitrogen-based synthetic fertiliser in SAR. Overall, urea accounted for 80% of the total fertiliser product used in SAR (at a total of 42,312 kt) in 2018. This can be illustrated (Figure 5) by distinguishing the contribution of urea fertilisers to overall NH_3 and N_2O emissions compared to other synthetic fertilisers. For example, in India NH_3 emissions from urea reached 3,685 kt in 2018, compared with only 422 kt from other N fertiliser types. It is evident from the data that NH_3 and N_2O emissions from urea fertiliser use have been increasing steadily from the late 1970s until 2018 in SAR. NH_3 emissions have also increased for 'other' synthetic fertilisers, but these varied somewhat over the years.

Figure 5. Estimated total emissions (kt) for a) ammonia (NH_3) and b) nitrous oxide (N_2O) from urea fertilisers and other synthetic fertilisers per country in South Asia from 1970-2018. Derived here from datasets reported by Crippa et al. 2021a; EDGARv6.1 air pollutants and greenhouse gases. Note: The darker shading indicates emissions from urea and the lighter shading indicates fertiliser emissions from other synthetic fertilisers. Emissions from other synthetic N fertilisers are substantially less than those emitted from urea fertilisers. Synthetic fertiliser emission estimates for Maldives and Bhutan are not reported by EDGAR.

a) Ammonia (NH_3)



b) Nitrous oxide (N_2O)



5. FERTILISER DATA SOURCE: FAOSTAT

To ensure comparability and reliability of data for all SAR countries, this policy brief focuses mostly on fertiliser and crop data sourced by FAOSTAT[8]. FAOSTAT provides data on nutrient nitrogen fertiliser production, import, export and agricultural use. It also provides separate data for fertiliser products, such as Di-ammonium Phosphate (DAP) and Urea, as well as for crop area and production.

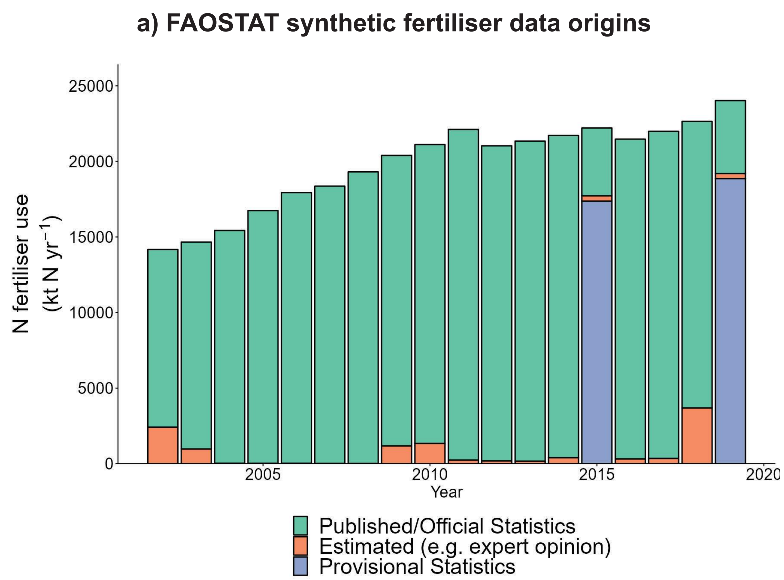
FAOSTAT data capture methods are broadly clear. For example, estimates of synthetic (inorganic) nitrogen fertilisers are reported at country-level and are primarily derived from questionnaires (FAO, 2022a) and official published statistics.[9] As seen in Figure 6 (a), for the period 2002 – 2020, SAR data has comprehensive coverage. Annual country-level estimates mostly use official published statistics. Figure 6(b) indicates a high correlation (r = 0.9) for India between the FAO dataset (orange line) and Indian national statistics of the Fertilizer Association of India (FAI) (blue line) for imported synthetic N fertiliser, which is encouraging,

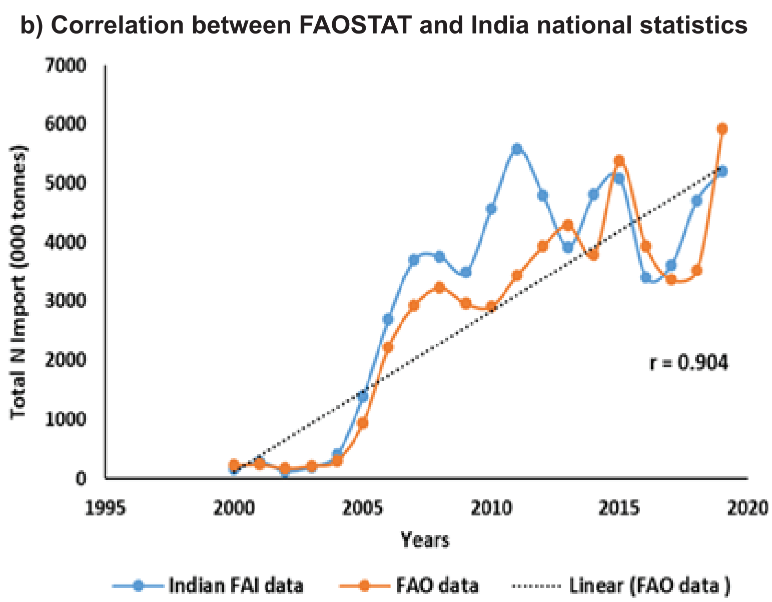
[11] https://www.fao.org/faostat/en/#home

[12] FAO imputes missing or non-usable data, primarily based on the aggregation of agricultural product data converted to nutrients, on balances based on the equation “production + imports = exports + agricultural use + other uses”, or on additional data (from associations, publications, etc.). Data are also discussed and quality checked with industry experts as part of an ongoing collaboration with FAO and the International Fertiliser Association (IFA).

although these datasets are not fully independent. The correlation is only slightly weaker when disaggregated further by fertiliser products or crop types (r= 0.8 - 0.7; for details see appendix). Although the data coverage for Afghanistan, Sri Lanka and the Maldives is less complete, they represent a small proportion of total SAR fertiliser use, when compared to India and Pakistan (see additional information in Section B. Data sources).

Figure 6. a) Synthetic nutrient nitrogen fertiliser (kt) used by South Asia countries from 2002- 2019. The figure is derived from data reported by FAOSTAT, 2022. Note: colours indicate the data origin of each estimate: green = published/official statistics; orange = derived/imputed estimates based on e.g. expert opinion or import/export statistics; and purple = provisional data**. b) Correlation analysis of FAOSTAT with Indian national statistics for the import of synthetic N fertiliser in India, from 2000 to 2020.** The figure is derived from data reported by FAOSTAT (2023) and FAI India (2019)





6. SYNTHETIC NITROGEN (N) FERTILISER: PRODUCTION, IMPORT, EXPORT & USE

The production, import, export and use of synthetic N nutrient fertiliser for the SAR countries are illustrated in Figure 7. Here major importers, exporters and producers are identified and how they relate to the overall use of synthetic nutrient N fertiliser.

Producers: There are four countries that produce synthetic N fertiliser in SAR. In descending order of synthetic N fertiliser quantity produced from 1980 to 2020, India produced the most, followed by Pakistan, Bangladesh and Afghanistan. Sri Lanka[10] and Nepal[11] briefly produced synthetic N fertiliser in the 1980s, but not since then. Further investigation into this data is needed to explain these patterns. India was the world's second largest producer of synthetic N fertiliser in 2020, and Pakistan occupied the seventh position.[12] Among all the SAR countries, India produced a maximum total N fertiliser at 13,745 kt in 2020, an increase of 535% from 1980. In Pakistan, production increased by 481% from 1980 to 2020. For Afghanistan, fertiliser production has been continuous, with peak production at 58 kt in 1990. However, these amounts decreased to 14 kt in 2020[13]. For Bangladesh, production has also been decreasing gradually since the early 2000s. The Maldives and Bhutan have not produced any synthetic N fertiliser.

Importers: All eight countries in SAR, even the biggest producers (India, Pakistan, and Bangladesh), import N fertiliser. India imported the most synthetic N fertiliser in 2020 at 6,719 kt, followed by Bangladesh at 371 kt, and Pakistan at 228 kt. Afghanistan, also a producer of N fertiliser, imported 29 kt of N fertilizer in 2020. Nepal, Sri Lanka, Bhutan and Maldives exclusively rely on imports, as they, at least since the late 1980's, do not produce synthetic N fertiliser. Sri Lanka imported 208 kt of synthetic N fertiliser, followed by Nepal at 142 kt Maldives at 0.23 kt, and Bhutan at 0.004 kt. Nepal's imports increased from 1980 to 2020 by 748%, although they dipped suddenly between 2002 and 2009. Sri Lanka's imports have been steadily increasing, and rose by 164% from 1980 to 2020. Where Sri Lanka's fertiliser production ceased in 1985 imports increased to meet demand.

Exporters: Countries with the ability to produce N fertiliser are most likely to export. The FAOSTAT data, shown in Figure 7, indicate that N fertiliser exports have been small relative to overall production and imports. This is understandable: most countries probably prioritise their own fertiliser needs. Most SAR countries have exported synthetic N fertiliser at some point, except for Nepal, Maldives and Bhutan. In 2020, India was the biggest exporter of synthetic N fertiliser (1,640 kt). India was responsible for exporting 99.8% of all SAR N fertiliser combined exports in 2020. FAOSTAT data indicates exports from India are minimal relative to overall production at just 0.6% of the total fertiliser produced in 2020.[14] Other countries indicated to be exporting fertiliser in 2020, with relatively minor amounts compared to India, included Sri Lanka (0.057 kt)[15] and then Pakistan (0.036 kt).

Data on export/import between recipient and supplier countries of synthetic N fertiliser was unavailable via FAOSTAT. The World Bank WITS[16] has data on exports for India, Pakistan and Sri Lanka. Nearly all of India's N fertiliser exports[17] were indicated to go to Nepal (98%), whereas Pakistan's N fertiliser exports mostly went to Afghanistan (73%), with smaller proportions to Sri Lanka (15%) and India (4%) in 2017. The WITS database estimates that 100% of Pakistan's imports came from countries outside of SAR. While Nepal received 11% of its imports from India and 89% from countries outside of SAR (see additional information ST Table 7).

Overall, the N fertiliser export data raises a number of questions around data availability and reliability. Further investigations are required to further understand the data and factors that influence export trends in SAR.

Agricultural use: A country's ability to produce and import fertilisers, will affect crop yields. These factors determine the type of fertiliser used, how it is used and, how excess nitrogen may enter the environment. Figure 7 indicates (dashed line) the estimated amounts of synthetic N fertiliser used in each country in SAR.

For most countries, production and imports (minus exports) together match the estimated total agricultural use[18]. In contrast, for Bhutan imports of N fertiliser have not always aligned with fertiliser use. For example,

[13] Production of N fertiliser in Sri Lanka peaked in 1982, at a total of 97 kt.

[14] FAOSTAT reports only a single year where there was N fertiliser was produced in Nepal, this was in 1983, and total of 29 kt.

[15] According to FAOSTAT (2022), China is the biggest synthetic N fertiliser producer in the world in 2020 (31,942 kt), followed by India (13,745 kt). Pakistan was the seventh largest producer (3,370 kt) in 2020.

[16] According to FAOSTAT, Afghanistan has produced 14 kt of synthetic N fertiliser consistently since 2014 to 2020.

[17] This explains why exports are not visible relative to the N fertiliser import, production and use amounts in India.

[18] Although Sri Lanka has not produced fertilizers since 1985, it nevertheless exports (e.g. to the Maldives) a fraction of its own fertilizer imports.

[19] World Integrated trade solutions (WITS) software provides access to international merchandise trade, tariff and non-tariff measures (NTM) data. **https://wits.worldbank.org/**

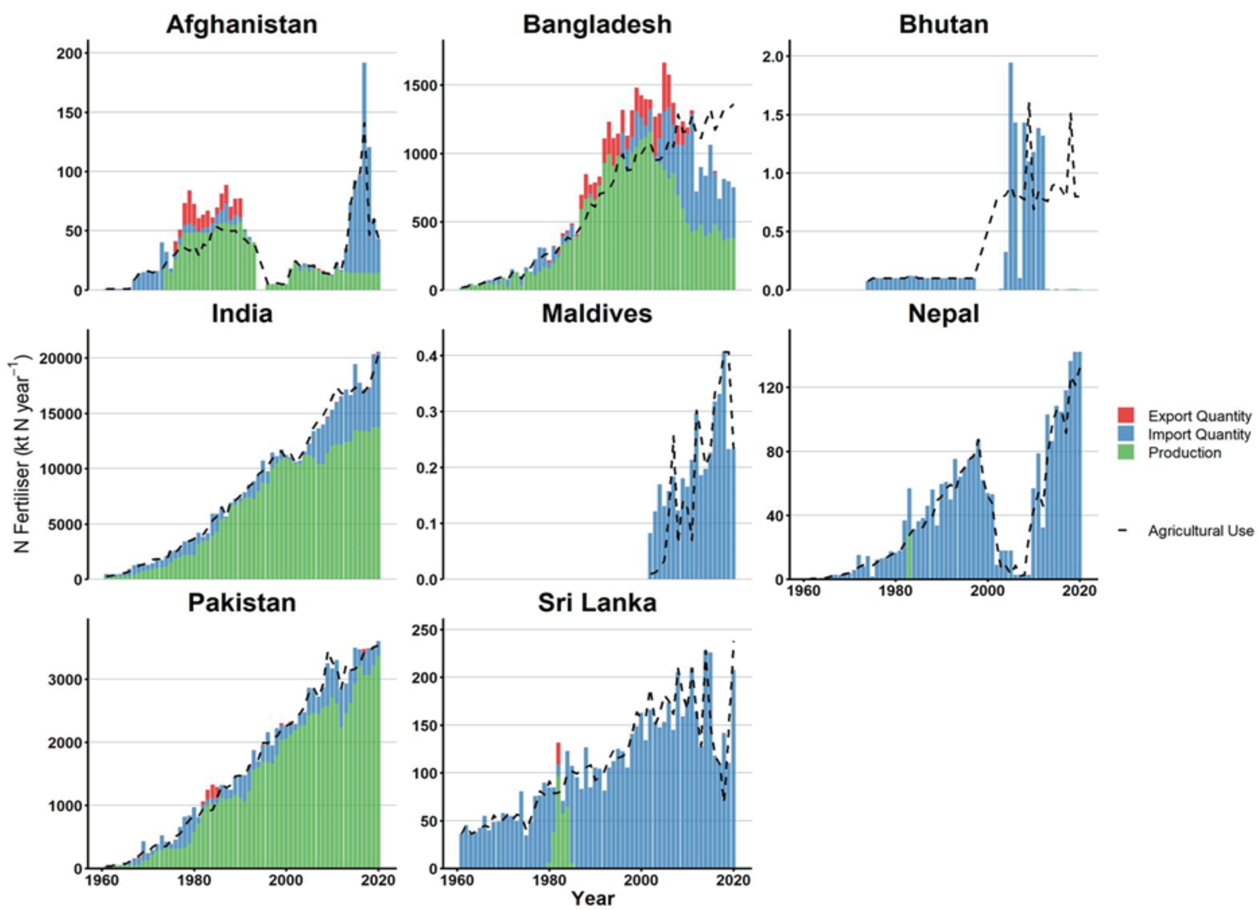
[20] This data is based on "Fertilisers, mineral or chemical; nitrogenous, urea, whether or not in aqueous solution" only and does not include other fertiliser products.

[21] Availability can be greater or equal to use.

N fertiliser use and import were aligned up until 2002, then from this point, imports and fertiliser use became more divergent. From 2003 to 2020 N fertiliser use averaged 1.1 kt and imports had a lower overall average at 0.54 kt. Fertiliser imports in Bhutan fluctuated from 0 – 1.4 kt between 2003 and 2020. In Bangladesh the FAOSTAT data also indicates that N fertiliser use exceeds imports and production. From 2008 onwards, N fertiliser use in Bangladesh, as indicated by the FAOSTAT data, is mostly below that of import and production[19] values. These results may indicate uncertainties in the FAO estimates, yet it may also be an indication of porous land borders (Shrestha, 2010).[20] In some cases, where production and imports exceed use, this could also indicate reserves.

Overall synthetic N fertiliser use in agriculture has been increasing steadily for India, Pakistan and Bangladesh (see Figure 7). However, for the other five countries in SAR the use of N fertiliser has undergone fluctuations over time, though overall trends indicate an increase. Sudden decreases are particularly evident for Afghanistan, Sri Lanka and Nepal.[21] Such fluctuations are likely to impact crop yields too, yet crop yields can be sustained and even improved through increasing NUE (Lassaletta et al., 2014).

Figure 7. Production, import, export and use of synthetic N fertiliser (kt) by South Asia countries from 1960 -2020. Stacked graphics showing the sum of the first three components, compared with estimated agricultural use, plotted using data reported by FAOSTAT 2022. Differences between production plus import minus export and agricultural use indicate uncertainties, changes in stored fertilizer and other N uses.



When the agricultural use of N fertiliser is standardised per capita and cropland (ha), a slightly different picture is evident (see Figure 8). Pakistan has the highest N fertiliser use per capita (10-20 kg N annually), followed by India (5-15 kg). Bangladesh and Sri Lanka have somewhat similar levels (~5-10 kg) for the period 1980-2020. In most countries, N fertiliser use per capita has increased over time; Afghanistan is the only country

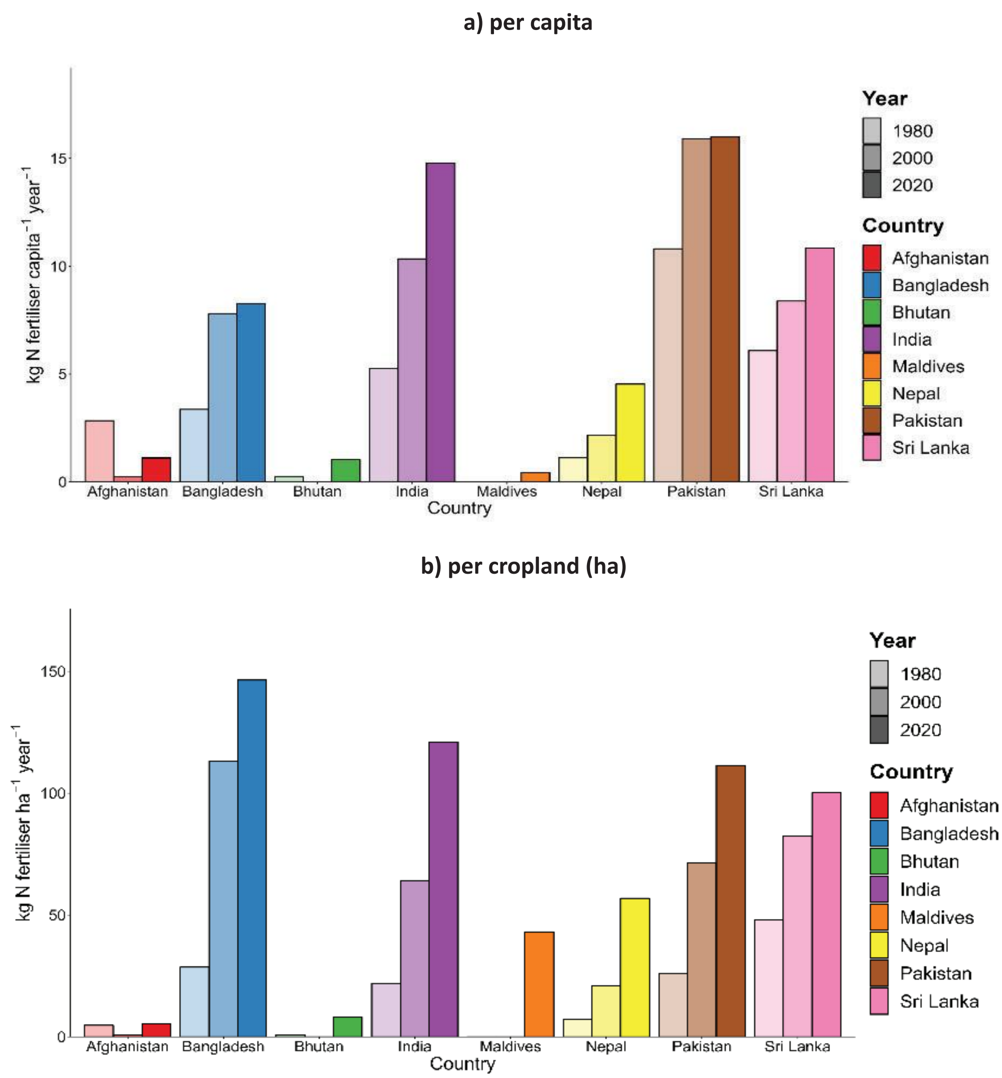
22 This could indicate an unused amount from the previous year.

23 In other words unofficially imported fertilizers that is supplied through a porous border such as between India and Nepal.

24 The reasons behind these fluctuations are being further investigated by SANH.

with a decreasing trend from 1980 to 2020. In terms of N use per cropland (ha), Bangladesh has the highest amount in 2020 (146 kg), followed by India (121 kg) and then Pakistan (111kg). N use per cropland area has increased over time for seven of the SAR countries. The exception again is Afghanistan, which had the lowest N use per cropland area in 2020 (5 kg), the same amount as reported for 1980. Since 2000, Maldives' N use per cropland per ha has been increasing and reached 43 kg in 2020.

Figure 8 Annual estimated use of synthetic nitrogen fertiliser (kg) for each South Asia country in 1980, 2000 and 2020: a) per capita b) per cropland hectare. These figures are derived from FAOSTAT 2022 data.



7. USE OF DIFFERENT FERTILISER PRODUCTS

The most commonly used nitrogen fertilisers in SAR are urea and di-ammonium phosphate (DAP). Further details are provided below on their use across SAR (see Figure 9).

Urea: Urea[22] is the most commonly used fertiliser product in SAR (44,384 kt in 2020). Increases in urea use have been higher than for DAP (see Figure 9). India has the largest consumption of urea in SAR (11,912 kt in 2020). This increased by 89% from 2002-2020.[23] A dip in urea consumption in 2016 may have been due to policies in India reducing fertiliser bag size from 50 kg to 45 kg and requiring the production of 100% neem-coated urea. Although this decrease (by about 3.3%) is notably less than the 10% reduction in bag size, while fertilizer use has continued to increase since 2017.

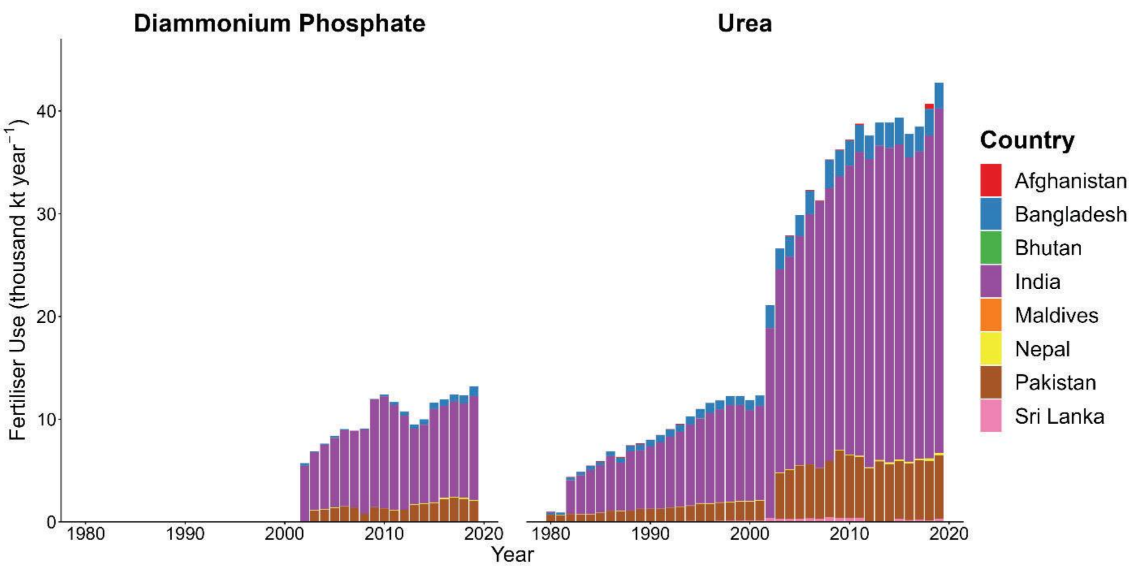
[25] The N content in urea is 46%.

[26] In India, Urea use increased from 2002 to 2020, from 16,549 kt to 35,043 kt.

Pakistan was the second largest consumer of urea at 6,039 kt in 2020. There were dips in use in 2007 and 2012, visible on Figure 9. Pakistan's urea use increased by 35% from 2003[24] to 2020. Nepal's urea use, although smaller to India, Pakistan and Bangladesh (at 225 kt in 2020), had the highest increase between 2003 and 2020 at 257%. In Bangladesh urea use increased by 17% and for Sri Lanka 35%. By comparison, there was little total consumption of urea by Bhutan and the Maldives, as seen for total fertilizer (cf. per capita fertilizer use Figure 8).[25] Urea use in Afghanistan has been sporadic and indicated to of ceased after 2017. Overall, India, Pakistan and Bangladesh were responsible for 98% of urea use, in 2020, across the SAR.

Di-ammonium Phosphate (DAP): The use of DAP[26] (15,163 kt in 2020) has remained fairly steady for many countries, relative to urea use from 2002 to 2019. India consumed the largest amounts of DAP relative to the other SAR countries, and has increased consumption[27], with some fluctuations. In India, DAP consumption increased by 118% from 2003 to 2020. Pakistan is the second highest consumer of DAP with an increase of 95% from 2002 to 2019, followed by Bangladesh, Nepal and Sri Lanka. There was zero to negligible consumption of DAP in Afghanistan, Bhutan and Maldives. India, Pakistan and Bangladesh accounted for 99% of DAP use in SAR, in 2020.

Figure 9. Fertiliser usage of a) Di-ammonium Phosphate (DAP) and b) Urea (kt) by each country in South Asia from 1980 - 2020. These figures are derived from datasets reported by FAOSTAT 2022.



8. CROP PRODUCTION, IMPORT AND EXPORT

Another N fertiliser use consideration is related to crop production, export and import (Figure 10). Crop imports support food security and demands in a country, but this can also lead to the displacement of N emissions and other forms of N pollution to the producing countries (Wang et al., 2022). Major food crops for SAR include wheat, rice and maize. These staple food crops are essential for regional food security (Mughal and Fontan Sers, 2020; Timsina and Connor, 2001). These crops are also associated with high annual N input rates, at about 90.7 kg/ha for paddy, 119.2 kg/ha for wheat and 68.7 kg/ha for maize in India, one of the major economies of the SAR (Ladha et al. 2016; FAI, 2019).[28] The percentage of N fertiliser use for cereal crop production in India was estimated of increased from 8–10% to 71–75% between the period 1961 to 2013 (Sapkota et al., 2022).[29]

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[27] Years vary slightly according to data availability.

[28] Maldives urea use in 2020 was estimated at 0.0925 kt. There were no urea use statistics reported for Bhutan in 2020 (FAOSTAT, 2023).

[29] The N content in DAP is 18%.

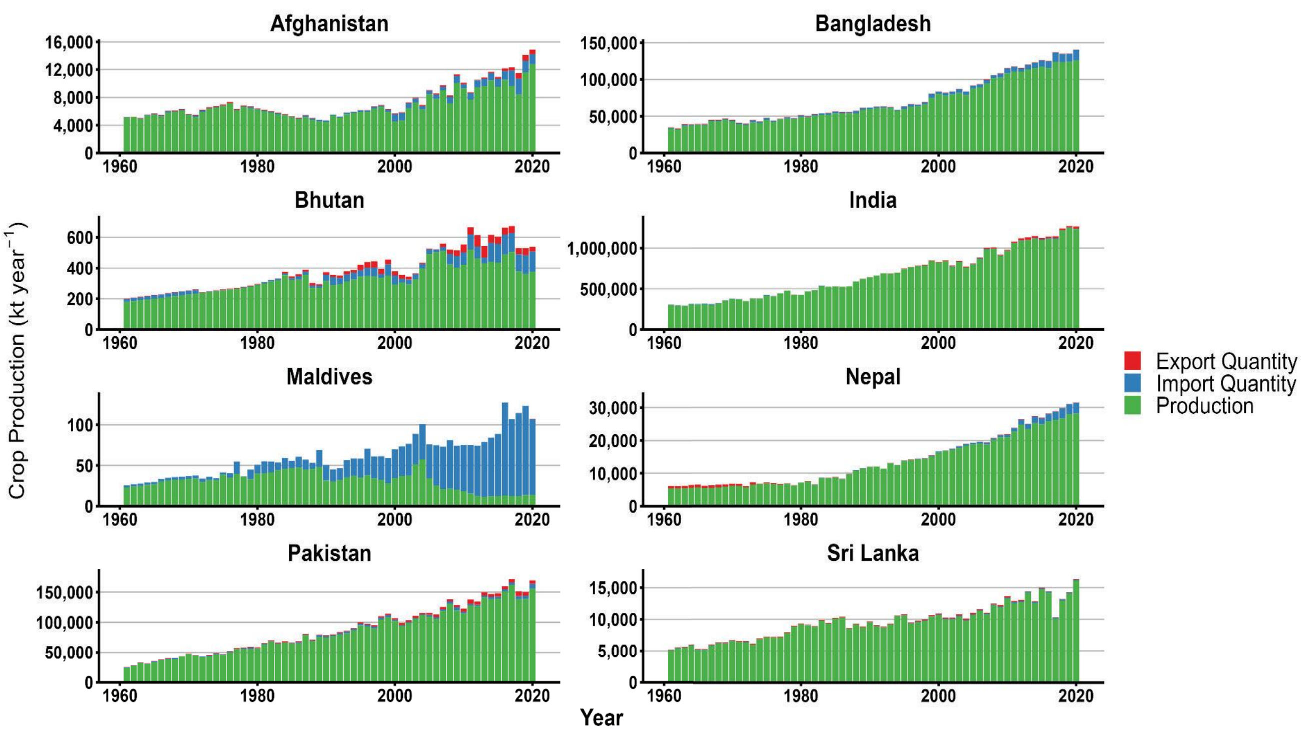
[30] The consumption data for DAP for 1980 to 2001 are not available for India with FAOSTAT.

[31] In India, rice, wheat and maize crops occupied approximately 42% of the total area harvested and 44%

[32] As per the Agriculture census (2021) 60% of the total N i.e., 9,051 kt were applied to only paddy, wheat and maize of total 15,009 kt of N applied to all crops during 2016-17 in India.

Crop production in all SAR countries increased, with some fluctuations between 1960 and 2020 and the Maldives is the only exception. Imports became increasingly important for the Maldives after 2000, coinciding with decreases in production. For the other countries, imports and exports are relatively small compared to overall production, indicating that the majority of the crops produced are kept for domestic consumption. Overall crop production is highest in India (1,117,704 kt in 2020) with the smallest production occurring in the Maldives (14 kt) and then Bhutan (318 kt). The challenges for food self-sufficiency in Bhutan include limited arable land, rugged terrain, the growing threat of climate-related risks and natural disasters, and impacts on seasonal water supplies (FAO et al., 2022). Bhutan, relative to its crop production, has a larger proportion of exports compared with other countries. See Section E for further details.

Figure 10. All crop production, import and export (kt) by each country in South Asia from 1960 - 2020. These figures are derived from datasets reported by FAOSTAT 2022



10. WAY FORWARD

This policy brief summarises how fertilisers have been crucial for meeting food demands, yet overuse and the associated nitrogen waste has been contributing to some of the world's most pressing problems. As stated in the UNEP frontiers report (2019, p.53) nitrogen *"threatens health, climate and ecosystems, making nitrogen one of the most important pollution issues facing humanity".* People in SAR are particularly vulnerable to environmental change, including climate change, due to a fragile environment, livelihood dependence on agriculture[30], alongside prevailing food insecurity (Wang et al. 2017; Mahapatra et al., 2021).

Agriculture, especially through the use of synthetic N fertiliser, is a major contributor to increasing N_r emission trends and ,driving environmental changes. The data presented here illustrate how agriculture is a major contributor to NH_3 emissions and N_2O emissions for South Asia (see Figure 1), where for many SAR countries, fertilizers alone are estimated to contribute 30% to 50% of total emissions (Figure 2). Nitrogen waste in the form of emissions to air and water also represents a financial waste of resources, where low NUE is accompanied by both losses of a valuable resource as pollution, and a requirement for larger amounts of expensive N_r inputs. This briefing further highlights the importance of crop production relative to total N use per country. More efficient use of fertiliser would not mean decreases in production, but a decrease in waste, with a higher proportion of the applied fertiliser being taken up by growing crops, rather than emitted to the

33 Agriculture is estimated to provide livelihoods to over 70% of the SAR population, in addition to providing employment for 60% of the region's labour force and contributes to 22% of the regional gross domestic product (GDP) (Wang et al. 2017)

air or runoff/leaching to soils and catchments.

New policies are being introduced across SAR in the wake of global price hikes in energy and fertilisers following COVID and the Russia-Ukraine war. As a result of these events global markets for food, fuel and fertiliser have been severely disrupted (Arndt et al., 2023). Increased costs to farmers are impacting food prices[31] for consumers and food availability. These disruptions are causing major concerns for poverty and global food security. It was estimated that that a total 27.2 and 22.3 million additional people could be driven into poverty and hunger, respectively (Arndt et al., 2023).[32] Many countries, including those in SAR, depend on fertiliser imports. Global fertiliser prices are estimated to have risen by 30% since early 2022, following an 80% increase in 2021 (The World Bank, 2022b). Policies continue to shift to manage the increasing energy and fertiliser costs, yet it is unclear if such decisions are evidence based. Fertilizer and related policies across SAR likely influence how fertiliser is accessed, traded and used, and therefore direct and indirect impacts N_r pollution. This requires further investigation.

Emissions of N_r including air pollutants like NH_3 and NO_x and the GHG N_2O are also set to rise if ambitious policy actions and measures are not implemented and a 'business as usual scenario' is followed instead (FAO, 2018). Agriculture is a priority area for action when it comes to sustainable nitrogen management across SAR and globally. Climate change mitigation and reductions to air and water pollution can be achieved via reductions to the overall production and use of synthetic N fertilisers (Menegat et al., 2022). By reducing nitrogen waste, and improving NUE in synthetic fertiliser use, crop production can be maximised whilst minimising harmful impacts.

SAR has the potential to lead the way globally in addressing the nitrogen crisis, considering previous and current advances in research and policy (Raghuram et al., 2021). The UN Environment Assembly resolution proposed by Sri Lanka with support from other SAR countries and adopted in March 2022 encourages *"Member States to accelerate actions to significantly reduce nitrogen waste globally by 2030 and beyond through the improvement of sustainable nitrogen management"* (UNEP/EA.5/Res2). The resolution highlights that safeguarding food security is a fundamental priority and achievable through sustainable nutrient use and decreasing nitrogen waste.

Science-based decision-making is crucial to move towards nitrogen sustainability. SANH is supporting this effort to create the scientific evidence of the sources and causes of emissions, and identify actions to mitigate impact. SANH will continue to improve the scientific and technical base and help strengthen SAR's contributions to address the causes and consequences of nitrogen waste. Further investigations into the role of policy in influencing fertiliser and N_r emission trends and patterns, as well as issues around data quality and availability are recommended.

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Supplementary Material: https://sanh.inms.international/policy/FertiliserPolicySupplement

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[34] The FAO food price index (a measure of the monthly change in international prices of a basket of food commodities) increased by 23% from May 2021 to May 2022 (FAO, 2022b; Alexander et al. 2022).

[35] In their study they focused on 19 countries and used national economy-wide models to measure the crises near-term impacts on agrifood systems, poverty, and food insecurity (Arndt et al., 2023).

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