

Section A. Reactive nitrogen emissions

Supplementary Table 1. Reactive nitrogen emissions for South Asia in 2018. These statistics are derived from datasets reported by Crippa et al. 2021a; EDGARv6.1 air pollutants and GHG.

Sector	Nitrous oxide (N ₂ O) Gg/2018	Nitrogen oxides (NO _x) Gg/2018	Ammonia (NH ₃) Gg/2018
Agriculture	964	676	10001
Energy Industries	52	7807	318
Industrial process and product use	1	25	38
Other	78	13	0
Other Energy	50	667	944
Transport	13	2454	30
Waste	81	336	279
Total	1,240	11,978	11,610

Supplementary Table 2. Total ammonia (NH₃) emissions (kt) from synthetic fertilisers (urea and other) in South Asian countries 1970-2018. These statistics are 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.

Year	Afghanistan	Bangladesh	India	Nepal	Pakistan	Sri Lanka
1970	4	32	334	2	82	12
1971	4	32	334	2	82	12
1972	4	32	334	2	82	12
1973	4	32	334	2	82	12
1974	6	21	384	2	84	16
1975	7	37	406	2	102	9
1976	7	42	511	2	116	12
1977	9	57	630	3	126	16
1978	8	57	657	3	155	19
1979	8	65	773	3	174	18
1980	9	67	797	4	183	22
1981	7	62	881	4	179	18
1982	9	76	930	5	205	19
1983	9	86	1072	6	197	20
1984	13	98	1226	7	195	23
1985	13	94	1318	7	235	25
1986	12	108	1511	7	290	24
1987	12	121	1325	9	279	25
1988	12	135	1648	9	291	26
1989	12	161	1639	11	330	26
1990	11	155	1740	11	332	22
1991	11	180	1848	12	332	23

1992	10	182	1947	14	371	25
1993	10	186	2044	13	383	28
1994	0	205	2215	16	402	30
1995	0	240	2304	17	461	28
1996	1	254	2434	18	461	29
1997	1	223	2545	18	483	30
1998	1	224	2645	21	488	35
1999	1	256	2677	14	511	41
2000	1	252	2523	13	519	39
2001	5	268	2618	12	531	40
2002	5	265	2426	12	543	40
2003	6	275	2579	12	588	37
2004	7	296	2712	5	649	37
2005	6	292	2936	1	685	35
2006	4	297	3192	1	606	36
2007	4	328	3365	1	693	34
2008	4	299	3495	1	718	42
2009	4	289	3563	1	821	43
2010	4	309	3772	2	733	44
2011	5	276	3955	3	748	44
2012	10	274	3918	14	660	42
2013	9	277	3942	23	733	44
2014	14	325	3969	20	762	49
2015	19	304	4025	26	602	60
2016	26	295	3883	25	835	37
2017	39	303	3930	27	767	29
2018	22	319	4107	16	770	34

Supplementary Table 3. Total nitrous oxide (N₂O) emissions (kt) from synthetic fertilisers (urea and other) in South Asian countries 1970-2018. These statistics are derived from datasets reported by Crippa et al. 2021a; EDGARv6.1 greenhouse gases. Synthetic fertiliser emission estimates for Maldives and Bhutan are not reported by EDGAR.

Year	Afghanistan	Bangladesh	India	Nepal	Pakistan	Sri Lanka
1970	0.28	2.00	25.35	0.14	5.37	0.80
1971	0.28	2.00	25.35	0.14	5.37	0.80
1972	0.28	2.00	25.35	0.14	5.37	0.80
1973	0.28	2.00	25.35	0.14	5.37	0.80
1974	0.38	1.30	29.01	0.14	5.70	1.17
1975	0.44	2.31	29.99	0.13	7.00	0.59
1976	0.48	2.61	36.95	0.17	8.03	0.82

1977	0.58	3.53	44.21	0.20	8.72	1.04
1978	0.56	3.57	47.08	0.22	10.75	1.26
1979	0.52	4.07	54.12	0.24	12.67	1.21
1980	0.59	4.18	55.35	0.26	13.24	1.44
1981	0.45	3.92	60.99	0.28	13.08	1.19
1982	0.61	4.79	63.53	0.36	14.99	1.25
1983	0.58	5.42	72.87	0.44	14.37	1.30
1984	0.83	6.04	83.81	0.50	14.68	1.51
1985	0.83	5.78	90.36	0.50	17.73	1.60
1986	0.79	6.65	102.59	0.52	20.94	1.56
1987	0.83	7.46	89.62	0.60	20.10	1.64
1988	0.78	8.31	112.47	0.63	20.82	1.67
1989	0.79	9.90	112.37	0.77	23.06	1.70
1990	0.69	9.57	118.88	0.81	23.13	1.45
1991	0.67	11.10	126.44	0.90	22.98	1.51
1992	0.61	11.21	132.42	0.93	25.71	1.61
1993	0.63	11.53	137.95	0.87	26.07	1.81
1994	0.00	12.64	149.39	1.04	27.31	1.95
1995	0.00	14.82	154.36	1.10	31.29	1.82
1996	0.08	15.65	162.11	1.18	31.20	1.85
1997	0.08	13.77	171.31	1.22	32.80	1.92
1998	0.09	13.87	178.41	1.37	32.87	2.23
1999	0.08	15.94	182.17	0.97	34.85	2.57
2000	0.08	15.65	171.45	0.85	35.59	2.47
2001	0.36	16.69	177.70	0.79	35.91	2.49
2002	0.33	16.50	164.51	0.80	36.92	2.55
2003	0.36	17.11	174.07	0.80	39.71	2.33
2004	0.41	18.44	184.09	0.30	43.76	2.39
2005	0.42	18.21	199.93	0.06	45.99	2.18
2006	0.53	18.42	216.45	0.11	41.64	2.24
2007	0.59	20.22	226.58	0.08	45.97	2.17
2008	0.64	18.44	237.13	0.13	47.69	2.60
2009	0.64	18.06	244.86	0.13	54.63	2.67
2010	0.64	19.44	260.20	0.24	49.38	2.75
2011	0.71	17.64	271.86	0.31	50.42	2.81
2012	0.64	17.48	264.32	0.97	44.83	2.68
2013	0.57	17.80	263.21	1.61	49.92	2.83
2014	0.87	20.76	266.35	1.35	52.06	3.13
2015	1.21	19.76	272.99	1.69	41.99	3.81
2016	1.67	19.00	262.98	1.64	58.61	2.38
2017	2.50	19.66	266.50	1.83	53.97	1.89
2018	1.39	20.75	277.16	1.09	51.34	2.17

Supplementary Table 4. Total nitrous oxide (N₂O) emissions (kg) in South Asian countries in 1980, 2000 and 2018, per capita and per crop area (ha). These statistics are derived from datasets reported by Crippa et al. 2021a; EDGARv6.0 and population data is from the World Bank (2022) and crop area data from FAOSTAT (2022). Synthetic fertiliser emission estimates for Maldives and Bhutan are not reported by EDGAR.

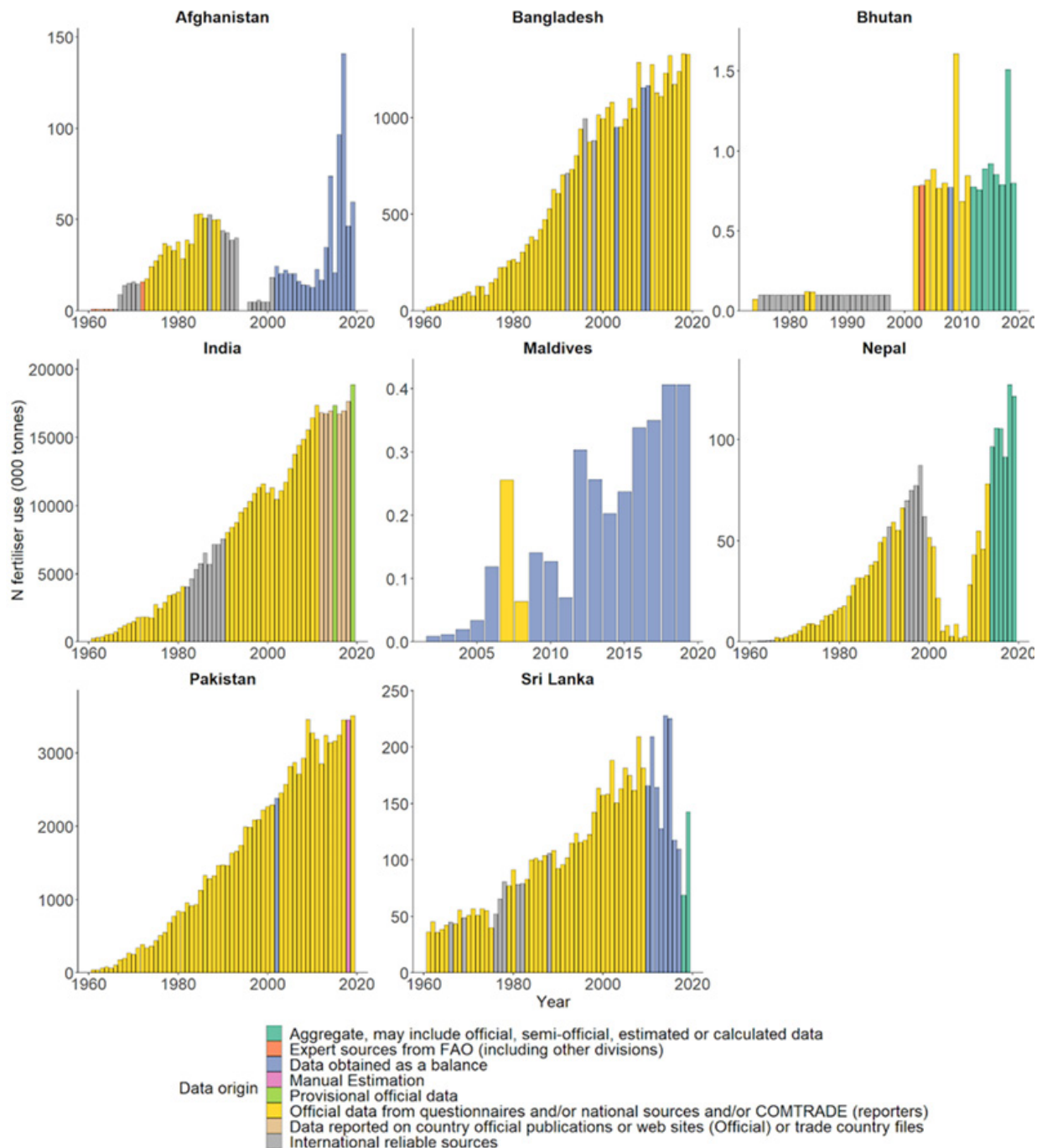
	Year	Afghanistan	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Total Nitrous oxide (N ₂ O) emissions (kg) per capita	1980	0.00004	0.00005	0.00008	0.00010	0.00002	0.00017
	2000	0.00000	0.00012	0.00016	0.00013	0.00004	0.00025
	2018	0.00004	0.00013	0.00020	0.00010	0.00004	0.00024
Total Nitrous oxide (N ₂ O) emissions (kg) per crop area (ha)	1980	0.07	0.45	0.33	0.11	0.41	0.75
	2000	0.01	1.78	1.01	0.34	1.12	1.30
	2018	0.17	2.31	1.64	0.47	1.61	0.92

Supplementary Table 5. Total ammonia (NH₃) emissions (kg) in South Asian countries in 1980, 2000, and 2018 and per capita and per crop area (ha). These statistics are derived from datasets reported by Crippa et al. 2021a; EDGARv6.0, and population data from the World Bank (2022) and crop area data from FAOSTAT (2022). Synthetic fertiliser emission estimates for Maldives and Bhutan are not reported by EDGAR.

	Year	Afghanistan	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Total ammonia (NH ₃) emissions (kg) per capita	1980	0.0007	0.0008	0.0011	0.0002	0.0023	0.0015
	2000	0.0001	0.0020	0.0024	0.0005	0.0036	0.0021
	2018	0.0006	0.0020	0.0030	0.0006	0.0036	0.0016
Total ammonia (NH ₃) emissions (kg) per crop area (ha)	1980	1.14	7.13	4.74	1.57	5.63	11.43
	2000	0.16	28.59	14.83	5.21	16.37	20.45
	2018	2.71	35.44	24.34	7.06	24.11	14.28

Section B. Data sources

Supplementary Figure 1: Agricultural nitrogen fertiliser use by South Asian countries from, 1960 -2020 and the FAOSTAT data source is illustrated. These statistics are derived from datasets reported by FAOSTAT (2022).



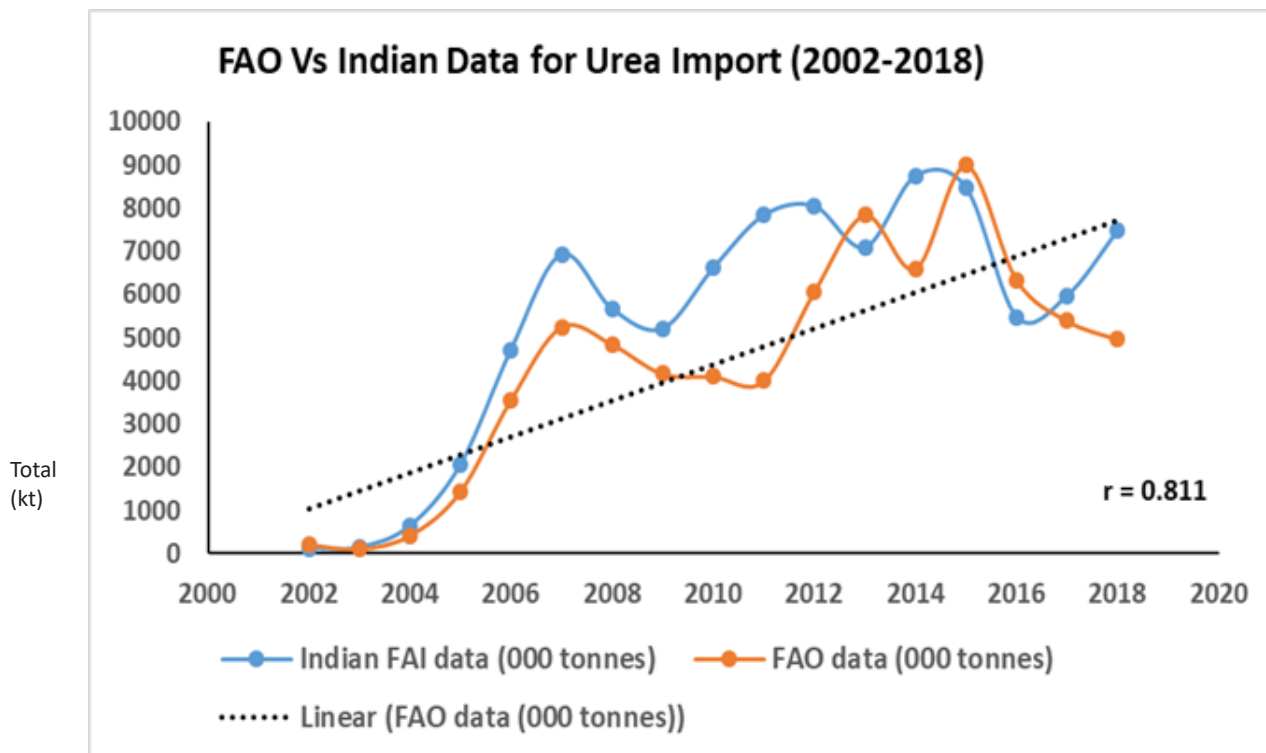
Note Figure 1: Agricultural use of fertilisers refers to the use for crops, livestock, forestry, fisheries and aquaculture, excluding use for animal feed. The FAO sources agricultural nitrogen fertiliser data directly from official questionnaire responses and/or national data for the majority of years for India, Pakistan, Bangladesh and Sri Lanka. Where national totals do not exist, the FAO has derived totals for some years, although these contribute a relatively small proportion overall (with the exception of Sri Lanka and Afghanistan in the last decade). There is likely to be a higher level of uncertainty associated with the totals for Nepal, Bhutan, Afghanistan and Maldives. Aggregate and gap filled data have been used for a number of years, potentially due to a lack of data availability.

Uncertainty analysis examples comparing FAOSTAT with Indian national statistics

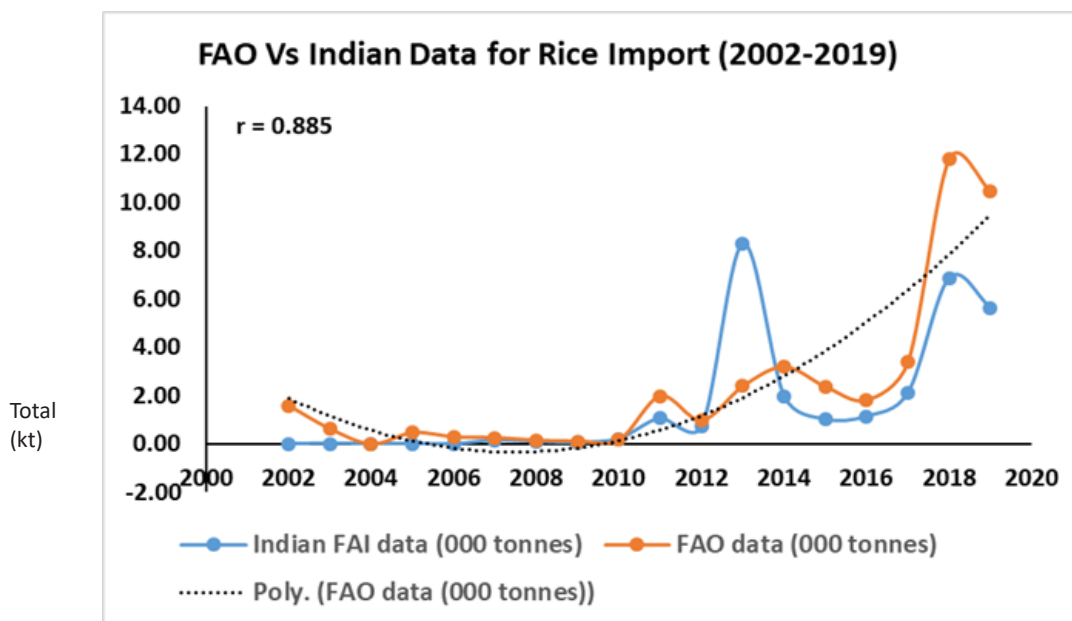
As outlined in the policy brief, FAOSTAT is the most reliable data source to provide a consistent assessment across the SAR countries. As further evidence of FAOSTAT as a reliable source, an uncertainty analysis was conducted on import and export data from India comparing FAOSTAT data with that of the Fertilizer Association of India (FAI, 2019). This similarity may well be because the datasets for India are presumably not fully independent but draw at least partially on some of the same input.

Further examples comparing the two dataset are provided in Figure 2-3. Figure 2 provides the data for imported urea fertiliser from FAOSTAT (orange line) and national statistics for India (blue line), with a high correlation between the two ($r = 0.81$). Figure 3 provides the data for imported rice with a high correlation ($r = 0.89$).

Supplementary Figure 2. FAOSTAT vs Indian national statistics for urea fertiliser imports in India, from 2000 to 2020. These statistics are derived from datasets reported by FAOSTAT (2022) and FAI (2019)



Supplementary Figure 3. FAOSTAT vs Indian national statistics for rice imports in India, from 2000 to 2020. These statistics are derived from datasets reported by FAOSTAT (2022) and FAI (2019).



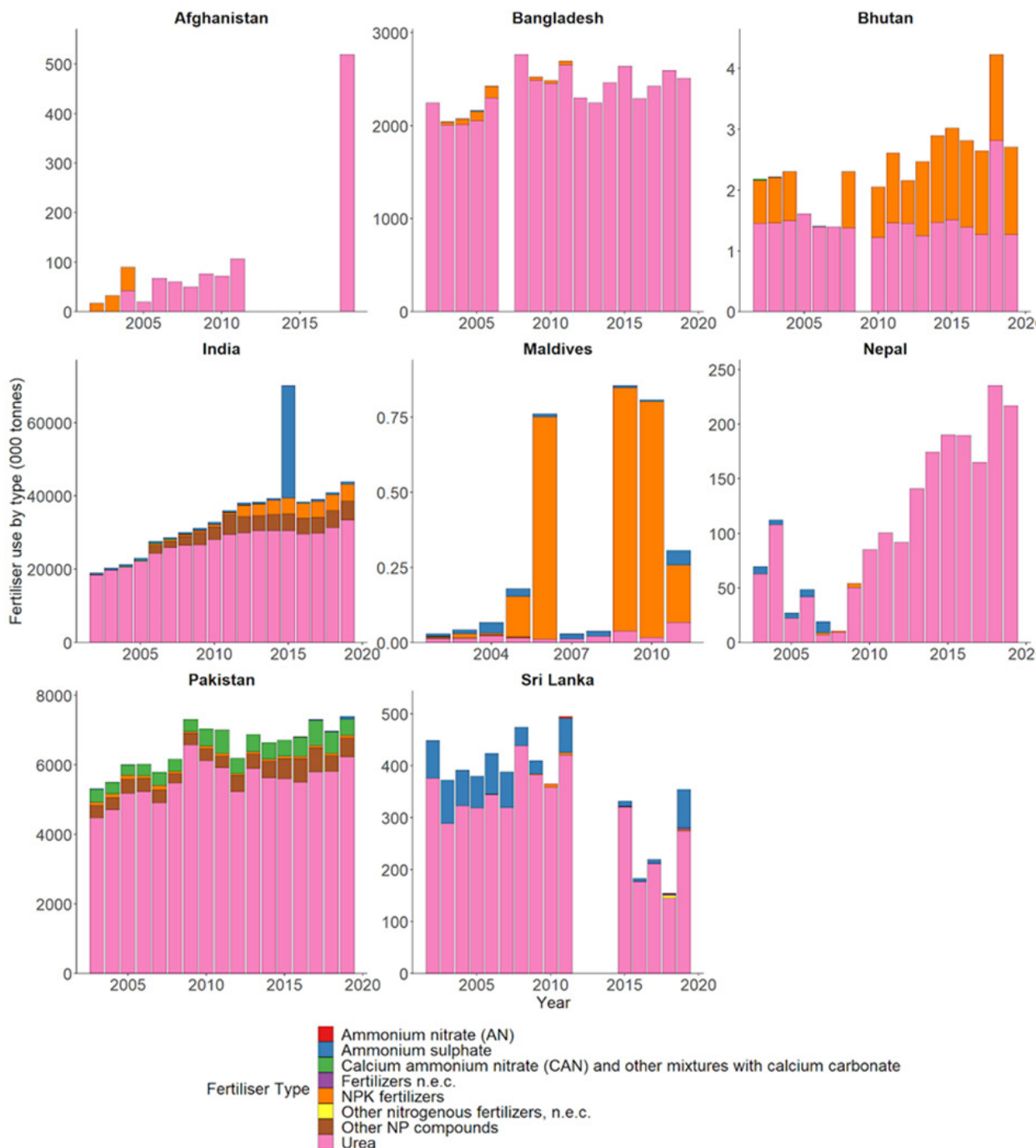
Section C. Synthetic nitrogen fertiliser use

Supplementary Table 6. Total Synthetic nitrogen fertiliser use (kt) by South Asian countries from 1980 - 2020 and year. These statistics are derived from datasets reported by FAOSTAT (2022)

Year	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
1980	37.8	267.9	0.1	3678.1	0	16.8	843.6	91.6
1981	28.7	251.6	0.1	4068.7	0	18	832.6	78.5
1982	38.8	304.9	0.1	4042.9	0	22.9	954.1	79.4
1983	36.8	344.9	0.1	4637.3	0	28.1	914.3	83
1984	52.8	384.7	0.1	5333.3	0	31.7	934.5	100.3
1985	53.2	367.8	0.1	5750	0	31.7	1128.1	101.7
1986	50.7	423	0.1	6528.7	0	32.9	1332.6	99.3
1987	52.8	474.6	0.1	5702.9	0	38.1	1281.7	103.9
1988	49.8	528.6	0.1	7157.5	0	39.8	1324.5	106
1989	50	629.8	0.1	7150.9	0	49.3	1467.6	108.5
1990	44.1	609.2	0.1	7565.5	0	51.8	1471.6	92.4
1991	42.8	705.6	0.1	8046.3	0	57	1462.9	95.8
1992	38.9	713.3	0.1	8426.7	0	59.4	1636.3	102.2
1993	40	733.6	0.1	8778.9	0	55.3	1659.4	115.1
1994	0	803.5	0.1	9507.2	0	66.4	1738.1	123.8
1995	0	943	0.1	9822.9	0	70	1991	115.9
1996	5	996.1	0.1	10315.9	0	75	1985.1	117.6
1997	5	876.6	0.1	10901.9	0	77.4	2087.6	122.5
1998	6	882.5		11353.8	0	87.4	2091.9	142.2
1999	5	1014.7		11586.3	0	62	2218.1	163.8
2000	5	995.9		10920.2	0	51.8	2264.6	157.5
2001	18.4	1054.2		11310.2	0	47.2	2291.6	158.4
2002	24.5	1079.1	0.8	10469.2	0	21.8	2385	188.3
2003	20.4	951.3	0.8	11077.9	0	5.5	2456	150.7
2004	22.3	954	0.8	11712.7	0	8.1	2570.2	163.2
2005	20.5	993.3	0.9	12723.9	0	2.9	2818.8	181.6
2006	20.5	1098.9	0.8	13760.9	0.1	8.8	2869	175.2
2007	16.4	1048.5	0.8	14417.7	0.3	1.9	2714.1	161.6
2008	14.4	1287	0.8	14863.8	0.1	2.8	2928.1	209.4
2009	14.2	1156.1	1.6	15558.4	0.1	28.3	3451.9	181.7
2010	12.9	1166.8	0.7	16450.7	0.1	43.1	3270.5	166.1
2011	23	1274.8	0.8	17367.5	0.1	54.8	3187.3	209.4
2012	17.1	1129.8	0.8	16820.9	0.3	46	2850.8	164.3
2013	34.9	1111.7	0.8	16750.1	0.3	78.3	3239.6	127.8
2014	73.9	1230.3	0.9	16949.6	0.2	96.7	3139.3	227.8
2015	92.5	1320.9	0.9	17372.3	0.2	105.8	3160.5	150.1
2016	96.7	1172.3	0.9	16735.4	0.3	105.7	3241.9	117.8
2017	140.8	1240.4	0.8	16958	0.4	91.6	3446.9	109.7
2018	46.6	1330.6	1.5	17628.2	0.4	127.3	3446.9	68.8
2019	59.7	1327.8	0.8	18863.9	0.4	121.5	3505.4	142.9

2020	43.1	1361.9	0.8	20404	0.2	132.2	3533.8	237.7
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Supplementary Figure 4. Agricultural fertiliser use in South Asia by fertiliser product type, country and year. These statistics are derived from datasets reported by FAOSTAT (2022). The majority of years use official statistics (shown in yellow and orange), with some missing years gap-filled. Compared to the nutrient N trends there are large fluctuations between years. Urea use is indicated by the colour pink.



Section D. Snapshot of export and import of synthetic N fertiliser between countries

Supplementary Table 7. Export and import of synthetic nitrogen fertiliser in 2017/18 (this includes Fertilisers, mineral or chemical; nitrogenous, urea whether or not in aqueous solution only). These statistics are derived from datasets reported by World Bank/WITS 2022.

Country	Trade Flow	Recipient country	Quantity (kt)	Quantity % Total
India	Export	Nepal	58	98
		Sri Lanka	0	0
		Other countries	1	2
		Total	59	100
Pakistan	Export	Afghanistan	53	73
		Sri Lanka	11	15
		India	3	4
		Other countries	6	8
		Total	73	100
Sri Lanka	Export	Maldives	1	100
		Other countries	0	0
		Total	1	100
Nepal	Import	India	22	11
		Other countries	181	89
		Total	203	100
Pakistan	Import	Other countries	109	100
		Total	109	100

Note: The WITS data does not include all countries and data is disaggregated for different fertiliser product types. Therefore the above table indicates 'part' of the synthetic N fertiliser flows between countries. Data is underreported on fertiliser import and export for the SAR with reduced reliability. Data can be accessed from: <https://wits.worldbank.org/trade/country-byhs6product.aspx?lang=en#void>.

Section E. Notes on major cereal crop production, imports, and exports

Major cereal crop production:

Rice production: Among all the SAR countries, India has the largest maximum rice area and production. Throughout the years, both area as well as production has increased continuously. India occupied around 40152 ('000 ha) area in 1980 which has increased to 43780 ('000 ha) by 2019, an increase of 8%. However, production has increased by 54% from the year 1980-2019. Bangladesh has the second largest area and production of rice with an increase of 10% and 61% respectively from 1980-2019 followed by Pakistan, Nepal, Sri Lanka and Bhutan.

Maize production: India is the biggest producer of maize, followed by Pakistan and Bangladesh. In these three countries production has been increasing more steadily since around the year 2000. Nepal has the next highest maize crop area and production rate, which has been steadily increasing since the 1980s. In Bhutan the rate has remained approximately similar over the period. By contrast, Afghanistan had production levels in line with Nepal in 1980's (~450,000 ha) but both the amount of maize produced and cropland area have been reduced since this time.

Wheat production: India (at 107,590 kt in 2020) followed by Pakistan are the biggest producers of wheat, compared to the other SAR countries. However, Afghanistan is the third biggest wheat producer in the region, producing 95185 kt in 2020. However production has fluctuated dramatically since the 1980's, indicating unstable yearly supplies. Nepal is the fourth biggest producer of wheat in the region.

Major cereal crop imports:

Rice imports: In Afghanistan, imports of both wheat and rice increased (with dramatic fluctuations) with

time since 1991, whereas import of maize remains were mostly negligible and this has been constant over time. Afghanistan's rice imports reached 500 kt in 2020. In Bhutan, rice is the most imported crop, compared to the other cereal crops, showing an overall rise over time, despite extreme fluctuations across the years. Imports peaked in 2020 at ~200 kt. In Bangladesh the rice imports were more than Maize but have fluctuated continually since the 1980's. A similar pattern is indicated for Sri Lanka, although a slight increase in imports since 2012 is visible. In contrast for India rice imports have remained very low to zero, likely indicative of India's own ability to produce rice domestically. A similar pattern is visible for Pakistan (low to zero rice imports over time). Maldives rice import trends are somewhat similar to Nepal's. Rice is the most imported cereal crop for the Maldives gradually increasing over time with a rise in particular since 2016. In 2020 Maldives rice exports peaked at ~70 kt. Nepal indicates a similar trend with rice as the most imported cereal crop, becoming increasingly important since the year 2000. In 2020 Nepal's rice imports peaked at ~2,000 kt.

Maize imports: Maize imports have remained low to zero, relative to other cereal crops, for the majority of the SAR countries (Afghanistan, Maldives, Pakistan, and India). Bangladesh, Nepal and Bhutan indicate low imports but with slight increasing trends. Bangladesh imported ~2,300 kt, Nepal 548 kt and Bhutan ~18.8 kt tonnes in 2020. Maldives imported negligible amounts of maize (0.07 KT in 2020). In Sri Lanka imports of maize have slightly increased but remained low, compared to the other cereal crops. In 2020, Sri Lanka imported 30 kt of maize.

Wheat imports: Wheat is the most imported cereal crop for the majority of the SAR countries (Afghanistan, Bangladesh, Sri Lanka, Pakistan and India) yet imports have fluctuated over the years. In 2020, Afghanistan imported ~500 kt, Bangladesh imported the most amounts of wheat compared to the other SAR countries, at ~6,000 kt and Sri Lanka imported 1,400 kt. Whereas for Pakistan India wheat imports have been low to zero in recent years, in India imports peaked in 2017 at 5,300 kt and Pakistan imports peaked at 2009 at 3,100 kt. For Bhutan wheat is their least imported cereal crop, and imports of wheat have remained low and fluctuated slightly since 1980 - 2020. In contrast wheat is barely imported by Maldives, with peaks in 1986 at 3 kt. In Nepal, wheat is also the least imported cereal crop but imports have started to rise from 2011. Nepal imported 297 kt of wheat in 2020.

Major cereal crop exports:

Rice exports: Exports of rice remain low in most SAR countries and even then the exports have fluctuated greatly over the years from 1980 to 2020. Maldives had zero rice exports. Afghanistan and Bhutan both had the lowest rice exports compared to other countries in the SAR (except Maldives). Bhutan rice exports peaked in 2002 at around 7 kt, whereas Afghanistan had a lower peak export in 2019 at around 0.9 kt. Bangladesh exported a large amount of rice in 1982 (40 kt) and then began to export again after 2004, and peaked again in 2007, and fluctuated since that time point. Nepal was indicated to have exported rice in the early 1980's until 1987. Exports peaked to 120 kt in 1986. After this point rice exports in Nepal were then negligible, with a few sporadic export years in 1999 and 2003 with relatively smaller export amounts (less than 5 kt). Sri Lanka rice exports also fluctuated, peaking in 1994 at just under 90 kt, which then dipped to around 5 kt, experiencing a second but lower peak (60 kt) in 2012. India and Pakistan are the only two countries that have had more subtle fluctuations and an overall increasing export trend between 1980 to 2020. India exported the highest amount of rice in 2020 at around 30,000 kt, and Pakistan followed with 8,000 kt in 2020.

Maize exports: In Afghanistan, Bhutan and Nepal, maize exports have been very low. There was no export of maize from Maldives. Maize exports were mostly negligible in Bangladesh, except in the year 2017, when 61 kt of maize was exported. Maize exports in Sri Lanka are also low and have fluctuated since 2010, peaking in 2013 at 0.74 kt. Pakistan also had negligible exports until 2008 and then exports continued to rise and then peaked in 2012 at 365 kt, which then reduced and fluctuated in subsequent years. India experienced a similar pattern but with a peak export of 4,750 kt of Maize in 2013.

Wheat exports: Exports for wheat have also remained low for most of the SAR countries, with some sporadic peaks in exports from 1980 to 2020. Maldives had zero wheat exports except in 2020 when it exported 0.63 kt. Similarly, for Afghanistan, maize exports were zero until one peak in 2020 with a very low amount (0.02 kt). Bhutan wheat exports are mostly zero, except between 1991 and 1999 with small amounts exported, peaking in 1993 (1 kt). In Nepal wheat exports have been sporadic, but mostly zero, and peaking once in 2009 (44 kt). The data indicates that Bangladesh exported 3 times, and only then a small amount of wheat, with a peak in 2006 (0.7 kt). India, Pakistan and Sri Lanka have experienced somewhat similar wheat export trends. Wheat exports for India have fluctuated (with no rising trend in this case) and peaked in 2003 (~4,000 kt) and

2013 (~6,500 kt). Similar fluctuating exports from the 2000 onwards were also experienced in Sri Lanka and Pakistan, with one off larger peaks both in 2011 (22 kt tonnes Sri Lanka, and 2,000 kt for Pakistan).

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