# BANGLADESH NITROGEN POLICY REPORT: SCIENTIFIC EVIDENCE, CURRENT INITIATIVES AND POLICY LANDSCAPE

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South Asian Nitrogen Hub (SANH)

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Photo Courtesy: BSMRAU SANH research team

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## Copyright and disclaimer

## FOREWORD - Message from the Vice Chancellor of Bangabandhu Sheikh Mujibur Rahman Agricultural University

This national report is the first of its kind in Bangladesh and is a major milestone towards ensuring sustainable nitrogen management for the country. It is the collaborative effort of BMRASU and the UKRI GCRF South Asian Nitrogen Hub (SANH) that enabled this report and the analyses of nitrogen related policy issues for Bangladesh within the broader South Asian context. Nitrogen management is crucial for sustainable production and environmental pollution, while pollution abatement does not always get the recognition in academia, research and the policy arena.

This report is unique in many dimensions outlining the impacts of nitrogen on people and the environment, summarizing the national context, identifying the nitrogen emission trends and sources, and analysing the current nitrogen related policy landscape. It highlights the issues and challenges around nitrogen pollution and management with recommendations for action.

By taking an interdisciplinary approach to nitrogen-related issues, this effort facilitates the science-policy interface to help identify risks and propose solutions for nitrogen management. Pragmatic and detailed scientific discussion in this report emphasizing the relationship between science and policy makes appealing to a range of stakeholders including the Government of Bangladesh. The sector and sink specific analyses outline the linkages between nitrogen pollution sources and impacts. In addition, identifying the opportunities and barriers for adopting efficient nitrogen management will support the development of effective policies and actions.

Environmental issues have always been a high priority of BSMRAU's academics and research agenda. BSMRAU focuses on issues that can contribute in attaining national and internationally set development targets by solving the real-life challenges. I appreciate SANH's approach as it goes beyond the international targets like UN Sustainable Development Goals (SDGs) and focuses on the national issues and policies.

Finally, I commend our BSMRAU and SANH colleagues for their efforts in bringing this wonderful compendium on nitrogen policy landscape in Bangladesh. I sincerely hope that this report will be well circulated and explored by experts beyond national boundaries.

**Professor Dr. Md. Giashuddin Miah**
**Vice-Chancellor**
**Bangabandhu Sheikh Mujibur Rahman Agricultural University**
**Gazipur, June 2022.**

## FOREWORD - Message from the Director of South Asian Nitrogen Hub

This report, prepared by the Bangabandhu Sheikh Mujibur Rahman Agricultural University in partnership with the UKRI GCRF South Asian Nitrogen Hub, without doubt represents a milestone in international cooperation on sustainable nitrogen management. The foundation of the Hub is closely linked to SACEP and nitrogen policy, with a key moment being the joint workshop on Sustainable Nitrogen Management between SACEP and the International Nitrogen Management System (INMS) held in Malé, September 2017. Key outcomes of the meeting included a draft resolution, which was ultimately adopted at the United Nations Environment Assembly's UNEA-4 in March 2019. Agreement to cooperate in a competitive proposal to UKRI ultimately established the GCRF South Asian Nitrogen Hub.

The work in this report represents one fruit of this cooperation between policy makers, and of social and natural science researchers into current nitrogen policies in South Asia, providing a foundation to inform future policy development. Apart from its immediate contribution to the SACEP Roadmap for Nitrogen Policies in South Asia, and the GCRF Nitrogen Hub, this document is also an important regional contribution to following up the Resolution on Sustainable Nitrogen Management at UNEA-4, which was led by India.

Actions in this wider policy context have since been accelerated by the Colombo Declaration in October 2019, which highlighted the need for National Roadmaps on Sustainable Nitrogen Management alongside a new ambition to 'halve nitrogen waste' from all sources by 2030. The policies presented in this report provide building blocks for the necessary change, and at the same time the opportunity for cleaner air, water, soil, less climate and biodiversity impacts, healthier lives and stronger economy. Globally, halving nitrogen waste could offer a resource saving worth 100 billion USD per year, which is a strong motivation for action.

The present report will be especially useful as we move forward. In addition to input to SANH, INMS and SACEP, other UN member countries can see comparative data and share lessons. We are celebrating the adoption in February 2022 of a new Resolution on Sustainable Nitrogen Management at UNEA-5. This encourages countries 'to accelerate action to substantially reduce nitrogen waste by 2030 and beyond'. Although Member States did not yet agree to 'halve nitrogen waste', this new resolution is the first time that such a reduction intent for nitrogen waste has been agreed universally by the UN, and it is therefore a major step forward to the UN Sustainable Development Goals (SDGs). The information and the lessons from the present report are therefore very timely in providing support to turn this ambition into reality.

**Prof Mark Sutton**
**Director UKRI GCRF South Asian Nitrogen Hub**
**Edinburgh, June 2022**

## FOREWORD - Message from the Director General of South Asia Cooperative Environment Programme (SACEP)

As a pioneer Regional Environmental Organization, South Asia Co-operative Environment Programme (SACEP) organization has been pursuing efforts to establishing Regional Framework Policy on Nitrogen Management which will support national effort and facilitate collective regional action on Sustainable Nitrogen Management and is pleased to be collaborate with UKRI GCRF South Asian Nitrogen Hub (SANH) and BMRASU in preparing and Publishing this historically important report for our member state Bangladesh.

As most of our member states, Bangladesh's economy also largely dependent on agriculture. The increased crop production has resulted in an increase in consumption of Nitrogen fertilizer in Bangladesh. And therefore, it is important to improve nitrogen management in agriculture, save money on fertilizers and make better use of manure, urine and natural nitrogen fixation processes.

This Nitrogen Policy Report for Bangladesh aims to understand the current Nitrogen policy landscape in Bangladesh and present the problems and challenges around nitrogen pollution and management. I am hopeful that the collated information in this report will raise awareness of the problems of nitrogen pollution among policy makers in Bangladesh to better understand Nitrogen management scenarios and their possible impacts on the environment and will support cleaner and more profitable farming and industrial recycling of nitrogen, fostering development of a cleaner circular economy for nitrogen.

Finally, I would like to render my heartfelt gratitude to all SANH experts, scientists and government agencies in Bangladesh and other parts of the world for developing this important and valuable policy paper which will ultimately help the region in managing nitrogen sustainably.

**Dr. Md. Masumur Rahman**
**Director General**
**South Asia Cooperative Environment Programme (SACEP)**
**Colombo, June 2022**

## Executive Summary

Growing anthropogenic demands have caused the production of excessive nitrogen and its consequent release into the environment. Nitrogen pollution and associated greenhouse gas emissions have increased, and at a much higher rate in recent decades, for almost every sector (e.g., agriculture, transportation, and industry). Major threats imposed by excessive nitrogen in the atmosphere include those to water quality, air quality, ecosystem and biodiversity and greenhouse gas balance. Provisioning, regulating and cultural ecosystems can be directly and indirectly affected by nitrogen, which can further be intensified by interacting with climate change and land use change. Adverse climate change impacts can be controlled through proper management of atmospheric nitrogen emission. Nitrogen pollution does not respect country boundaries. Hence, Government and Non-government measures (e.g., legislation, regulatory or financial), combined with trans-national cooperation can support and encourage nitrogen management efficiently.

The management of nitrogen is a major issue for international policy. International policy actions can be more easily tracked but information on nitrogen related policies and guidelines are scarce at the local level. There is limited understanding on nitrogen pollution in different sectors, on policies related to the phenomena, on how the issues are being addressed, and on the types of mitigation measures being undertaken.

An initial international assessment attempted to address the knowledge gap by creating the world's first nitrogen pollution policy database. Kanter et al. (2020) identified 2726 policies across 186 countries derived from the ECOLEX database, aiming to identify the gaps and opportunities in reactive nitrogen ($N_r$) policy, around the world. Overall, their analysis revealed that policy integration was limited and ill-equipped to deal with the cross-cutting nature of the global $N_r$ challenges. Moreover, they pointed out that the regional and country-level implications of the $N_r$ policy database were yet to be examined. Doing so for South Asia is a core aim of SANH. An initial regional assessment of nitrogen emissions and policy was undertaken by SACEP and SANH (2021) for South Asia, the results of which are summarized in a regional report. These regional results were further featured in a scientific journal article (Yang et al. 2022).

This report aims to understand the current $N_r$ policy landscape in Bangladesh. The report presents the problems and challenges around nitrogen pollution and management along with an overview of the $N_r$ issues at national, regional, and global scales. The methods and results from the SANH $N_r$ policy dataset have been highlighted, accompanied by an analysis of the drivers of $N_r$ emission and policy trends in Bangladesh. Furthermore, case studies illustrating some significant $N_r$ control policies have been provided alongside general recommendations and emerging issues.

The severity of atmospheric pollution in Bangladesh is reflected by the position of Dhaka (the capital and primate city) as the 3rd most contaminated city in the world. Environmental pollution in Bangladesh is largely caused by the agriculture, transport and industry sectors.

The major three $N_r$ compounds of global concern are the GHG nitrous oxide ($N_2O$) and the two ambient air pollutants nitrogen oxides ($NO_x$) (which includes nitrogen dioxide ($NO_2$) and nitric oxide (NO)) and ammonia ($NH_3$). Use/release of all three compounds (ammonia, nitrogen oxide and nitrous oxide) have increased over time in Bangladesh. While the largest change has occurred in the case of $NO_x$ emissions, which increased by 228% from 2000 to 2015, there was almost an equal percentage of increase (30% and 31%) in terms of $NH_3$ and $N_2O$ emissions in the same time period.

In Bangladesh, agriculture was by far the largest contributor of $NH_3$ (85%) to the overall total in 2015 and over the last few decades, while in terms of $NO_x$ emission, transport (25%) and industry (power industry, 43% and other industrial combustion, 15%) sectors are the major contributors.

The collected nitrogen related policies were classified based on certain characteristics to identify patterns in the types of policies in place for each country. Such a study on nitrogen pollution issues and related policy overview is the first of its kind in Bangladesh. In total, 187 policies (19% of the total SANH database) including those with both direct and indirect relevance to $N_r$ were classified, considering their direct and/or potential impacts on $N_r$ management. Policies were then classified by environmental sink, sector, sub-sector, policy type, pollution source type, impact direction, impact scope and relevance.

Policy type, as a classification category, indicates what type of policy instruments are being suggested or applied within a particular policy. A single policy may have multiple policy type characteristics e.g., framework, data and methods and research and development (R&D). For Bangladesh there were 279 classifications from the 187 policies, within which 39% (74) policies referred to multiple policy types and the most common classification for policy type was found to be framework (61%) which include policies with broad objectives and/or designated governing bodies. Most of the collected policies were completely single sector oriented (as 73% of policies did not refer to any environmental sink), among which the agricultural sector was found to be the most common classification (35%).

A favourable combination includes policies having multiple sectors and sink as they indicate 'integrated objectives' that consider the environment as well as multiple sectors, but the percentage of this combination was found to be quite low (5%) in Bangladesh. Framework policies focusing on agricultural sector dominates among all the single sector policies (20%). Again, multiple sectors were linked to some certain policy types including framework (8%), R&D (4%), data and methods (1%) and regulatory (1%). These multi-sectoral policies associated with multiple policy types are the most suitable policies for better $N_r$ management. In Bangladesh 67% of policies (119 of total 187) were identified as of medium to high relevance and scope, since such policies have the potential for higher impact on how $N_r$ enters the environment. Still, policies with lower scope and relevance should not be completely discounted since they might have the potential to influence $N_r$ management and could be amended to promote sustainable management. For instance, despite being classified as having indirect relevance the 'Fish and animal feed act 2010' can impact $N_r$ pollution through discharge and waste management principles.

In response to the adverse effects of rapid industrialization, urbanization and population growth on the environment, the highest number of policies were developed during 2011-2019. Only 21% of nitrogen related policies were developed before 2000, rising to 24% during 2001-2010, and 55% of such policies were formulated during 2011-2019 (a 31% rise from the previous years). A rising proportion of the policies in every time duration were sector specific, more specifically they were directed towards agriculture (7% in pre-2000, 9% in 2001-10 and 19% in 2011-19) in Bangladesh.

Agriculture, industry, and transport have shown sharp increases in the levels of $N_r$ emission. Emissions of nitrogen from agriculture, industry and transport sectors into the global environment have increased more than 10-fold over the last 150 years. In Bangladesh, industry, transport, and agriculture are the major sources or drivers of $N_r$ pollution. Increased food demand, largely pushed by population and economic growth, promoting the increased use of chemical fertilizer and forcing higher production in limited land all have contributed to release of nitrogen from agriculture. Agricultural use of chemical fertilizers in Bangladesh has increased over time. For instance, the use of urea fertilizer in agriculture has increased by 11.7% since 2002. The agricultural sector accounted for 85% of ammonia ($NH_3$) emission during 2015 in Bangladesh. Furthermore, the industry sector accounts for substantial emission of $N_r$ pollutants. Thus, the power industry in 2015 contributed 43% and other industrial combustion contributed 15% of the total nitrogen oxides ($NO_x$) emissions. Although the transport sector has a major responsibility for $PM_{10}$ and $PM_{2.5}$ pollution, it is also a major source of $N_r$ pollution. $NH_3$ (85%), $NO_x$ (68%) and $N_2O$ (83%) emissions from the transport sector have been increasing strongly over time (2000-2015).

Nearly half of the classified policies had positive impact direction (44%) followed by mixed/neutral (37%). Despite current policy efforts, and some encouraging areas, all N compounds of concern are increasing. Therefore, more needs to be done in policy at multiple scales, i.e., supporting international, regional, national and sub-national movements to deliver sustainable N management; sustainable N management will also assist in meeting all 17 SDGs.

The findings from this report provide insights on policy gaps and opportunities, which further help to develop recommendations (Section 8) for better nitrogen management. Notably, diverse policies that address multiple environmental sinks and/or economic sectors and are associated with multiple policy types, are preferable and more effective to confront multi-dimensional challenges of nitrogen management. Interactions between sectors need to be considered alongside potential impacts on environmental sinks. Similarly, sink focused policies, such as those focused on air quality, soil, climate, ecosystems, and water, are best when they identify the risks from sector-based activities with options to mitigate adverse impacts. Moreover, the use of multiple rather than single policy instruments, and a broader range of regulatory actors, will also produce better regulation outcomes. Action-oriented and nitrogen-specific policies (i.e., promoting technologies that emit less nitrogen) and/or guidelines to enforce rules and/or laws for different sub-sectors at national and sub-national levels are urgently required to promote lower $N_r$ emission.

This report is an initial effort to create awareness relating to nitrogen management policy landscape in Bangladesh. But the issues of insufficient data and quality limit our analysis and are barriers to understanding the various synergies and conflicts that might arise in policy formulation. Support for research into possible ways of circumventing the conflicts between various human system goals is an important step that should be taken quickly.

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# 1. Introduction

## 1.1. Lead institution and SANH

The South Asian Nitrogen Hub (SANH) is a UKRI GCRF funded research partnership that brings together 32 leading research organisations and project engagement partners from South Asia and the UK. SANH is working towards enabling South Asia to 'adopt and champion a strategic approach to nitrogen management, as a key step towards the Sustainable Development Goals'. SANH aims to provide relevant scientific insights, identify barriers to change, and demonstrate the economic benefits of tackling nitrogen pollution.

SANH includes eight South Asian countries: Afghanistan, Pakistan, India, Nepal, Bhutan, Bangladesh, Maldives and Sri Lanka. These eight countries are also partners in the South Asia Co-operative Environment Programme (SACEP), which outlines a shared vision for a 'healthy environment, resilient society and regional prosperity for the present and future generations' for the 2020 - 2030 decade.

SANH research programmes focus on the following four key areas:

1. Building the nitrogen policy arena for South Asia;
2. Testing options for improving N management, from agricultural practices to technological recapturing;
3. Studying the impact of nitrogen pollution on the key ecosystems, corals and lichens;
4. Building an integrated framework to look at nitrogen flows between land, water and atmosphere across the region.

**Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU)** is a government-financed public university of Bangladesh. The vision of the university is to foster quality teaching and research that develop highly skilled and educated people necessary to advancing the well-being of the nation in general and farming communities in particular. Currently the university has five faculties providing undergraduate and post-graduate degrees in different agriculture-related discipline.

Climate change is a core focus area of BSMRAU's research. Involving national and international collaborators, BSMRAU has implemented several research projects for varietal and technological development and improving the farming practices that are resilient to the changing climate and can contribute to mitigate the adverse effects of the changing climate and facilitate farmers' adaptation process. The university prioritizes the changing climate in the academic program, which is evident from the increasing number of graduate level thesis related to climate smart technology. While the bio-science related departments work for the development of technologies and their impact on production and environment, the social-science disciplines focus on farm level adaptation, impact on farmers' livelihood and possible policy intervention. In the process the university does not confine itself to academic and research only, rather it directly works with farmers for better dissemination through its outreach program.

## 1.2. What is the purpose of this report?

This report is part of SANH actions towards building the nitrogen policy arena for South Asia. It is one of the many planned activities of SANH which specifically focused on the evaluation of current policies, progress and barriers across different scales within each of the eight countries.[1] Our approach firstly looked at the regional scale and now aims to focus on the national scale.[2] Even though it is critically important for life and the environment, nitrogen is not often given a high profile in academia, or in research and policy arenas. For example, studies focusing on air pollution were mostly concerned with carbon monoxide and hydro-carbon (e.g. Sources of Air Pollution in Bangladesh by DoE, 2012) and the studies regarding water pollution are primarily focused towards salinity and arsenic pollution in Bangladesh (e.g., 'Quality unknown: the invisible water crisis', Damania et al. 2019). Nitrogen and different $N_r$ pollutants have been topics of less concern (DoE 2012). Through attempting a multidisciplinary holistic approach to understanding the nitrogen policy landscape in Bangladesh, given the complexity of the nitrogen management system, which is challenging to incorporate in a single report, or study, this report may not always satisfy the diversified interests of readers. Rather, we publish this report to build awareness by providing an initial identification of nitrogen emission trends and sources, and analysis of the current nitrogen related policies in Bangladesh. The findings of this report aim to contribute towards the understanding of how to build an efficient nitrogen management system for the country and reduce $N_r$ waste.

This report provides a necessary step to understanding the current nitrogen policy landscape for Bangladesh within South Asia. Similar national level reports are being prepared for each of the eight SACEP member countries.

The report is structured in the following way:

i. Issues and challenges around nitrogen pollution and management.
ii. Overview of the nitrogen issues at the global and national scale.
iii. Methods and results from the SANH nitrogen policy dataset.
iv. The drivers of emissions and policy trends at the country level.
v. Case study overview into some significant nitrogen control policies.
vi. Emerging issues.
vii. Recommendations.

## 1.3. The way forward[3]

In Bangladesh, no prior attempt was made to reveal the nitrogen policy landscape. At the national level, we hope this report can be taken as the basis of initiating discussion with government and different

[1] This report is a continuation of several earlier important activities of the Global Environment Facility (GEF) funded project '*Targeted Research for improving understanding of the global nitrogen cycle towards the establishment of an International Nitrogen Management System (INMS),'* which is targeted to bring real change in improving nitrogen management system through science-based evidence on the nitrogen cycle and sustainable practices.

[2] A joint publication by SACEP and SANH provides a regional overview of the nitrogen policy in South Asia (SACEP/SANH Report 2022). In addition, a regional policy analysis has been prepared for academic publication, and the South Asia case study will form part of a chapter in a global nitrogen assessment being prepared by the International Nitrogen Institute.

[3] For earlier international nitrogen initiatives please visit INMS (https://www.inms.international/) and future plans of SANH are available on the project website: (https://sanh.inms.international/).

relevant stakeholders including science, businesses and civil society for identifying challenges and barriers towards designing and implementation of the nitrogen related policies.

The report is coherent with the spirit of the 'Resolution on Sustainable Nitrogen Management' at UNEA-5. Though countries are yet to reach an agreement on exact amounts of nitrogen waste to be reduced, this report will support and guide, not only Bangladesh but also other partner countries, towards adopting improved nitrogen management policies. We are aware that further supplementary studies are required to compile and assess the different nitrogen related complexities, particularly while designing specific policy interventions, and these may require further detailed analysis. This report should be recognised as a first attempt towards understanding nitrogen policy coherence at the national level, to identify the gaps and opportunities to support the development of national action plans for sustainable nitrogen.

The academic and science communities, irrespective of geographic boundary, will benefit from our data, methodology, and the insights we have gained. The report's findings can help to facilitate knowledge sharing and understanding between peers working in any dimensions of the environment and policy landscape in relation to nitrogen management both directly and indirectly.

### 1.4. Understanding the role of nitrogen in the environment[4]

Nitrogen, the most abundant element in the atmosphere, carries enormous significance for life. Despite its abundance in the atmosphere as $N_2$, it is largely inaccessible in this particular form, making it a scarce resource, further limiting primary productivity in many ecosystems (Bernhard 2010). Nitrogen exists in many forms, including both organic (e.g., amino and nucleic acids) and inorganic (e.g., ammonia, nitrate) (Bernhard 2010).

The major three $N_r$ compounds of global concern are the GHG nitrous oxide ($N_2O$) and the two ambient air pollutants nitrogen oxides ($NO_x$) (which includes nitrogen dioxide ($NO_2$) and nitric oxide (NO)) and ammonia ($NH_3$).

- **Nitrous oxide ($N_2O$)** is a GHG, with about 300 times warming potential of $CO_2$. It is another abundant $N_r$ compound that is of global concern with 40% of total $N_2$ generated by human activities.
- **Nitrogen oxides ($NO_x$)** is one of the dominating polluting compounds globally and in South Asia. Nitrogen dioxide ($NO_2$) which contributes to $NO_x$ amongst other pollutants, also features in $PM_{2.5}$ (a common proxy for air pollution)
- **Ammonia ($NH_3$)** is a key pollutant contributing excess nitrogen deposition on vulnerable ecosystems (UNECE 2019) leading to acid deposition and eutrophication. Ammonia also features as a component of $PM_{2.5}$. Therefore, efforts to reduce ammonia would also have co-benefits for mitigating $PM_{2.5}$ pollution (Wu et al. 2016).

[4] This section is a snapshot attempting to introduce readers to the complex nitrogen management system. The complexity varies across sectors and sinks. For a better understanding, a Massive Open Online Course (MOOC) on nitrogen is freely available at: https://www.inms.international/news/free-nitrogen-massive-open-online-course. For more in-depth learning on nitrogen please see *Our Nutrient World* (Sutton et al. 2013) available at: http://nora.nerc.ac.uk/id/eprint/500700/

Nitrogen is one of the most crucial elements in regulating primary production and species diversity in both aquatic and terrestrial ecosystems (Vitousek et al. 2002). For example, ammonia is the base for amino acid, proteins, enzymes and thus central to metabolism of all life forms. Similarly, $NO_x$ acts as a biologically signalling compound, while nitrate provides nutrient for plant growth (UNEP 2019a). However, human induced activities (e.g., burning fossil fuel, use of N-based fertilizers) are considerably impacting the nitrogen cycle as well as increasing the amount of biologically available reactive nitrogen. This can further lead to severe reactions in the atmosphere, water, soils and life-forms. Sutton et al. (2013) conceptualized the 'nitrogen cascade' and illustrated how a single atom of $N_r$ can trigger a cascade of negative environmental impacts in different sectors.

1.4.1. Impact of excess reactive nitrogen on the environment

In order to be biologically functional, the existing atmospheric nitrogen needs to be transformed into various reactive forms (UNEP and WHRC, 2007). Natural production of reactive nitrogen ($N_r$) is often not sufficient to meet the food demands of an increasing world population (UNEP and WHRC, 2007). Hence, nitrogen has been altered in order to produce chemicals, fertilisers, and other useful products (European Commission, 2013). Once in a reactive form, nitrogen is transported easily between air, water and soils, which can be termed as the nitrogen cascade (see Figure 1).

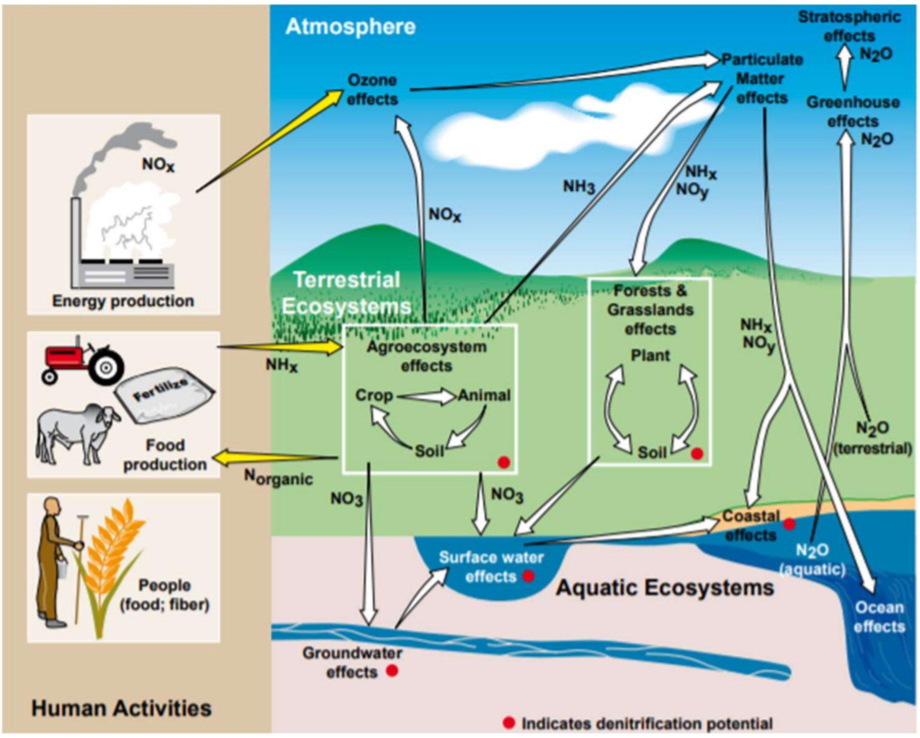



**Figure 1: Illustration of how reactive nitrogen flowing from energy and food production cycles among atmospheric, terrestrial and aquatic components of the biosphere**

Source: UNEP and WHRC (2007) and Galloway et al. (2003).

With increasing human activities, $N_r$ production has more than doubled during the last century (Sutton et al. 2011), leading to nitrogen pollution. Nitrogen pollution can be defined as compounds containing nitrogen which contribute to the disruption of the nitrogen cycle, causing environmental damage. $N_r$

compounds occur as gaseous air pollutants and include ammonia ($NH_3$), nitrogen oxides ($NO_x$), and nitrous oxide ($N_2O$). $N_r$ further occurs as water pollution in the form of nitrites ($NO_2$ -); nitrates ($NO_3$); and ammonium ($NH_4$ +) (EC 2013).

The five principal threats of nitrogen pollution resulting from excess $N_r$, as demonstrated by Sutton and Billen (2010) are to water quality, air quality, greenhouse-gas balance, ecosystems and biodiversity. For example, the German Advisory Council on the Environment (SRU) (2015) mentioned it can lead to:

- Nitrogen-induced eutrophication and acidification contribute to bio-diversity loss.
- Nitrous oxide damages the ozone layer and contributes to climate change.


**Figure 2: Threats from nitrogen pollution**

Source: Sutton and Billen (2010).

Provisioning, regulating, supporting and cultural ecosystem services can be directly and indirectly affected by $N_r$.[5] Impacts are further intensified via interactions with other human-caused environmental change, such as land use and climate change, along with other pollutants. For example, fertilizer runoff can cause freshwater eutrophication, leading to harmful algal blooms and dead zones and may destroy fish stocks (UNEP 2007). Nitrogen excess in North America has led to air and water pollution and degraded the environment in many ways. For example, the Chesapeake Bay, once a vibrant and functioning ecosystem, has been seriously degraded through air and water pollution because of over-fishing and under-protection. Again, the algal bloom in Lake Erie (Figure 3) has occurred due to nitrogen and phosphorus loading through agricultural runoff.

**Figure 3: Impact of agricultural runoff in Lake Erie between USA and Canada**

Note: Algal bloom (shown in milky green) in the west of Lake Erie between Canada and the United States on 3 August 2014. Lake Erie's frequent algal blooms are caused by nutrient phosphorus loading from agricultural runoff of fertilizers and manure, municipal wastewater effluent and atmospheric deposition. Source: UNEP (2019).

[5] Ecosystem services are defined as the ecological and socio-economic as well as religious-cultural value of goods and services provided by natural and semi-natural ecosystems (Erisman et al. 2013)

### 1.4.2. Impact of nitrogen pollution on human health

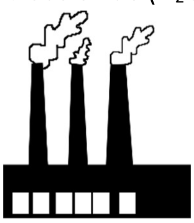
Nitrogen pollution threatens the environment in multiple ways with knock on effects for society. For example, the combined cost to ecosystems, climate and health was estimated at over €70 billion per year to the EU alone (Brink et al. 2011). Most of these costs were attributed to the adverse impacts on human health.

Though difficult to understand the mechanism completely, $N_r$-related pollutants are hazardous for human health and work through different pathways including pulmonary irritation, suppression of the immune system, and disruption of the autonomic nervous system etc. (Peel et al. 2013; Sacks et al. 2011). For example, $N_2O$ obliquely affects human health by navigating the $O_3$ depletion with further impacts on health through UV radiation (Peel et al. 2013), whereas gaseous $NH_3$ can directly hamper the health of those engaged in confined animal feeding operations (ATSDR 2011). Exposure to nitrates in drinking water can cause diseases like cancer, methemoglobinemia, enlargement of thyroid gland. (Parvizishad et al. 2017). Again, oxidized nitrogen can be fatal for infants and even if they can survive the early consequences, they can be scarred for life e.g., through impaired growth. Ingestion of nitrogen (in nitrate and nitrite forms) can kill infants by reducing their ability to transport oxygen, and can also cause methemoglobinemia, namely **blue baby syndrome,** if the nitrates' level in water rises above the standard 10 ppm. For example, infants born in India, Vietnam and 33 African countries exposed to higher nitrate levels in the first 3 years of life are stunted (Damania et al. 2019).

Airborne fine particles ($PM_{2.5}$) can cause the greatest health risk (US EPA 2019). Particle size is directly related to their potential for causing health problems. Secondary sulphate and nitrate particles are usually the dominant components of fine particles. Respiratory problems like coughs, bronchitis, wheeze and conjunctivitis symptoms were found to be all related to multiple pollutants such as $PM_{10}$, $NO_2$, $SO_2$, $O_3$ and are collinear to each other (WHO 2003). An example is APHEA2 (Air Pollution and Health: A European Approach 2) which depicted stronger mortality effect of PM in areas (29 European cities including London, Madrid, Zurich, Rome) with high $NO_2$ (Katsouyanni et al. 2001). This positive interaction was further interpreted by WHO (2003) as pointing that PM contains more noxious substances in places with high $NO_2$. According to the World Health Organisation (WHO), many of the world's most badly affected cities in terms of $PM_{2.5}$ pollution are in South Asia, accounting for the largest number of deaths and disabilities due to air pollution.

The direct and indirect environmental and health impacts of different nitrogen molecules are illustrated in Table 1. The table indicates where there are some overlaps between $N_r$ emission sources and impacts, and unique differences.

**Table 1: Overview of reactive nitrogen emissions and related environmental and health impacts**

| Emission | Source | Benefit | Environmental and Health impacts |
|---|---|---|---|
| Nitrate ($NO_3$)<br> | Wastewater, agriculture and oxidation of NOx. | Widely used in fertilizer and explosives. | $NO_3$ forms particulate matter (PM) in air and affects health. In water it causes eutrophication. |
| Nitric oxide (NO) and nitrogen dioxide ($NO_2$) – collectively known as $NO_x$ (nitrogen oxides)<br> | Combustion from transport, industry, and energy sector. | NO is essential for human physiology but $NO_2$ has no known benefit. | NO and $NO_2$ (or $NO_x$) are major air pollutants, causing heart disease and respiratory issues, e.g., asthma, respiratory disorder, inflammation of airways, reduced lung functions, bronchitis, and cancers. |
| Ammonia ($NH_3$)<br> | Manure, urine, fertilizers, and biomass burning. | $NH_3$ is the foundation for amino acids, protein and enzymes. Ammonia is commonly used in fertiliser. | $NH_3$ causes eutrophication and affects biodiversity. It forms particulate matter (PM) in air affecting health (See NO and $NO_2$ above).<br><br>- modest odour contribution |
| Nitrous oxide ($N_2O$)<br> | Agriculture, industry, and combustion. | Used in rocket propellants and in medical procedures as laughing gas. | Health impact due to global warming, often enhanced by eutrophication<br>health impact due to loss of stratospheric ozone depletion.<br><br>In addition, the enhancement of vectors for infectious diseases (e.g., malaria) and frequency of infestations (e.g., algae blooms, insects etc. |

Source: adapted from Erisman et al. (2013) and UNEP (2019).

South Asia contains several global hotspots for $N_r$ pollution both in larger cities and across the Indo-Gangetic plain. A regional overview of current $N_r$ emissions, trends and impacts for three main $N_r$ pollutants nitrogen oxides ($NO_x$), nitrous oxide ($N_2O$) and ammonia ($NH_3$) is available in SACEP & SANH (2022).

Figure 4 illustrates the hotspots for nitrogen dioxide ($NO_2$) atmospheric pollution. Figure 5 illustrates the extent of nitrogen oxide ($NO_x$) emissions across South Asia in 2015. The darker colours in the map represent those locations with higher emissions. Direct exposure and indirect exposure to $NO_x$ can lead to respiratory issues including lung damage. These emissions are often correlated with toxic pollutants from industry and transport. Transport is also a significant source for nitrogen oxides ($NO_x$) and particulate matter (PM) emissions (Kegl 2007).

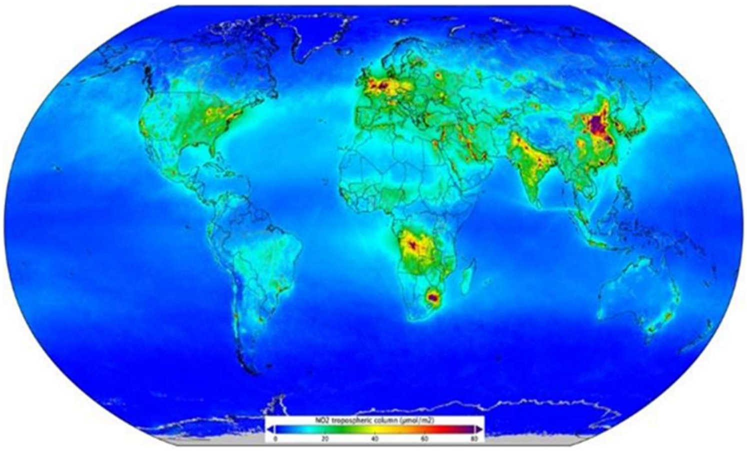



**Figure 4: Global map of $NO_2$ (nitrogen dioxide) atmospheric pollution**

Note: Low levels of pollution are dark blue running to dark red for highest levels.
Source: European Space Agency (2019).

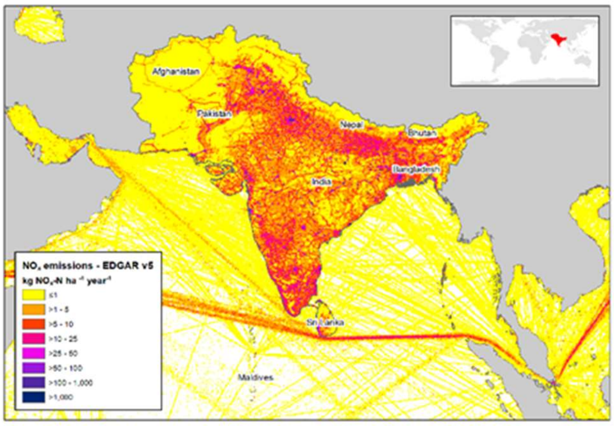



**Figure 5: $NO_x$ (Nitrogen Oxide) emissions across South Asia, 2015**

Note: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a)
The darker purple to blue colours indicate high concentrations of $NO_x$/ha/year.
Source: SACEP-SANH (2022).

Nitrogen pollution, in its reduced form, can occur in the air as ammonia ($NH_3$) and in the water as ammonium ($NH_4$ +). Ammonia ($NH_3$) is increasingly seen as problematic. The deposition of ammonia, both wet and dry, can lead to soil acidification, nutrient leaching, eutrophication, and ground water pollution (European Commission 2013). Agricultural activities reportedly account for approximately 80% – 90% of the overall anthropogenic ammonia emissions (Bouwman et al. 1997; Zhang et al. 2010).

Ammonia is considered to be more harmful to ecosystems than nitrogen oxides ($NO_x$) especially when deposited in its dry form (Hicks et al. 2011). South Asia is a global hotspot for ammonia emissions, as indicated in Figure 6. The extent of nitrous oxide ($N_2O$) emissions in South Asia is illustrated in further detail in Figure 7.

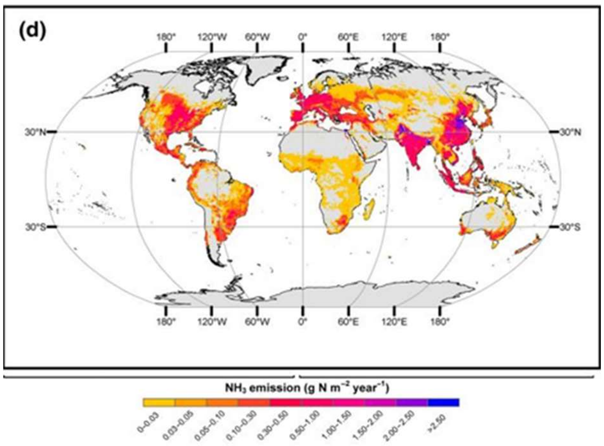



**Figure 6: Global map of $NH_3$ (Ammonia) emissions**

Note: This map is based off simulated ammonia emissions in response to application of synthetic nitrogen (N) fertilizer in the 2000s. Spatial resolution of 0.5 by 0.5 degree.
Source: Xu et al (2019).

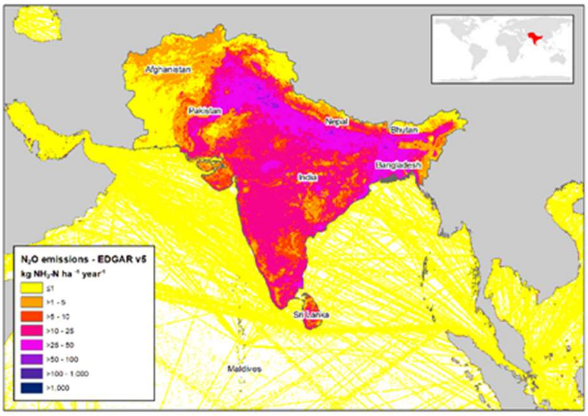



**Figure 7: Nitrous Oxide ($N_2O$) emissions across South Asia, 2015**

Note: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa, et al (2019a).
Source: SACEP-SANH (2022).

## 1.5. Addressing the offshoots from nitrogen pollution in the environment

The impacts of reactive nitrogen ($N_r$) are not simply bound to air or soil or water, so a comprehensive and coherent understanding of the issue and of its status is a pre-requisite (UNEP 2007). The problems associated with excess $N_r$ are commonly encountered in industrialized regions, while developing regions often face a combination of both excess and deficiency challenge (UNEP 2007). For example, in Latin America urban areas struggle with higher level of water pollution caused by sewage release, whereas rural areas tackle agricultural runoff and the adversity that follows this (UNEP 2007; Martinelli et al. 2006). Again, in Africa there are deficiencies of $N_r$ as farm input to meet their required food production target, while in some regions (i.e., Latin America) the environment is being harmed through over-utilization of $N_r$ as fertilizer (Elrys et al. 2020; Martinelli et al. 2006).

Whilst local sources of nitrogen pollution, such as air emissions and run off, contribute to local effects, they also can contribute to accumulations at subnational to global scales (Erisman et al. 2013). Nitrogen pollution does not respect country boundaries. Therefore, tackling nitrogen pollution requires trans-national cooperation.

SANH works across the eight South Asian counties to reinforce and support effective nitrogen management through a coordinated and integrated approach in the region. Collaborative efforts to tackle nitrogen are already underway (see section 1.7).

The Task Force on Reactive Nitrogen (2020) provided a guidance document on integrated sustainable nitrogen management focused on the agricultural sector. The document includes specific information on the principles and measures that can reduce $N_r$ emissions and leaching to water and total N loss.

Some examples of preventive measures to reduce reactive nitrogen in the atmosphere as suggested by Stevens (2019) include:

- Better management of animal waste in agriculture to reduce emissions.
- Precision agriculture to reduce fertilizer inputs.
- Changes in human diet to reduce high-nitrogen-footprint.
- Increased use of alternative energy sources.
- Reduction in biomass burning in transportation.
- Chemical scrubbing of industrial emissions to remove reactive nitrogen.

Effective policy development and proper implementation can limit the growing scale of the environmental, economic and health detrimental impacts of $N_r$.

## 1.6. How Can Policy Support Sustainable Nitrogen Management?

Governments may take a number of legislative, financial or regulatory measures in order to manage nitrogen pollution directly and indirectly. Additionally, measures both through government and outside of government can support and incentivise the management of nitrogen more effectively, minimising negative impacts. Multiple scales and actors also need to be considered in how to target actions.

Traditional policy interventions that deal with nitrogen management can include (Dalgaard et al. 2014):

1) *Command and control (C&C)* i.e., the classic regulation type, where an action or pollution practice is forbidden by law, controlled by the authorities, and fined if in violation.

2) *Market-based regulation and governmental expenditure (MBR)*, for example, when the management of pollution behaviour is regulated via market incentives, typically via a green tax (e.g. N-taxation) under the 'polluter pays' principle (Carter 2007) or when funds are provided to promote environmentally friendly behaviour.

3) *Information and voluntary action (IVA);* the promotion of sustainable N-management practices via knowledge production, communication, technologies as well as research and extension services. These actions may also be subsidised or funded by government(s).

Another approach for reducing nitrogen pollution increases the efficient use of nitrogen, particularly in agriculture (see box 1). Improving nitrogen use efficiency (NUE) in agriculture is becoming increasingly vital; as global food demands are set to grow by 50% – 100% by 2050 (Connor et al. 2011; FAO 2017).

**Box 1. Nitrogen Use Efficiency (NUE) in agriculture**

Agriculture is the economic sector with the highest nitrogen use and the main source of $N_r$ pollution (European Commission 2013). Nitrogen use in agriculture is often extremely inefficient; the global NUE of cereals decreased from 80% in 1960 to 30% in 2000 (Erisman et al. 2007), which highlights that the majority of fertiliser applied globally is wasted, with NUE decreasing over time. NUE is further reduced when widened out to the entire food system. Sutton et al., (2009 p.18) stated that:

*"The global food chain has a mean nitrogen use efficiency of 14% for plant products and 4% for animal products (meat, dairy, egg). The remainder is dissipated into the environment … to air, and … to groundwater and surface waters."*

Addressing NUE could provide a 'win-win scenario', argues Sutton et al. (2009). Studies have shown it could be both environmentally and financially beneficial. Improving NUE is a way to minimise damaging emissions of nitrogen whilst maximising the benefits gained (European Commission 2013).

Improvements to NUE require changes to agricultural practices. Scientists argue that sustainable agricultural practices, especially those closer to the natural systems are a way forward. Such practices can include "minimal tillage, intercropping, cover crops, catch crops, green manures (including legumes), animal manures, broad crop rotation, effective use of crop residues, and landscape planning" to reduce $N_r$ waste and increase NUE (Sutton and Billen 2010; European Commission 2013). Yet any intervention can have drawbacks and the suitability will be site specific. Policy itself plays a crucial role in guiding actions towards more efficient and effective nitrogen management.

An ambitious strategy for reducing the nitrogen emission will require a system that reflects the layout of the issue from various angles. Kanter et al. (2020b) identified a gap, where most policies aim to reduce N pollution at the farm level ignoring the multifaceted sources of nitrogen emissions. There are opportunities for interventions along the value chain, from fertilizer manufacturers, transportation, retailers, to consumption and wastewater treatment (Kanter et al. 2020b). One approach that takes this into account is 'the nitrogen circular economy'. This was adopted by the EU in 2015, aiming to maximise resource efficiency at all steps along the value chain (UNEP 2019).

Nitrogen pollution is not just an issue for agriculture. Considering the other sectors, such as energy, waste, industry, transport, urbanisation, and tourism, is also vital for addressing the global N challenge. For example, emissions of air pollutants from transport need to be tackled. National measures can include setting of limits or target values for ambient concentrations of pollutants, limits on total emissions (e.g., national totals) and regulating emissions from the traffic sector by setting emissions standards or by setting requirements for fuel quality (EEA 2021). Localised measures may include low-emission zones in cities and congestion charges.

Figure 8 gives some examples of 'other measures' that can promote clean air practices to reduce PM pollution. These are noted as the 25 'most effective' measures listed by the Climate and Clean Air Coalition (CCA). Figure 8 indicates some existing measures, those with recent legislation, and those with further potential for being implemented in Asia and the Pacific. Post combustion controls, clean cooking, industrial process emissions, along with emission standards for road vehicles are the measures indicated to have the most impact in reducing $PM_{2.5}$.

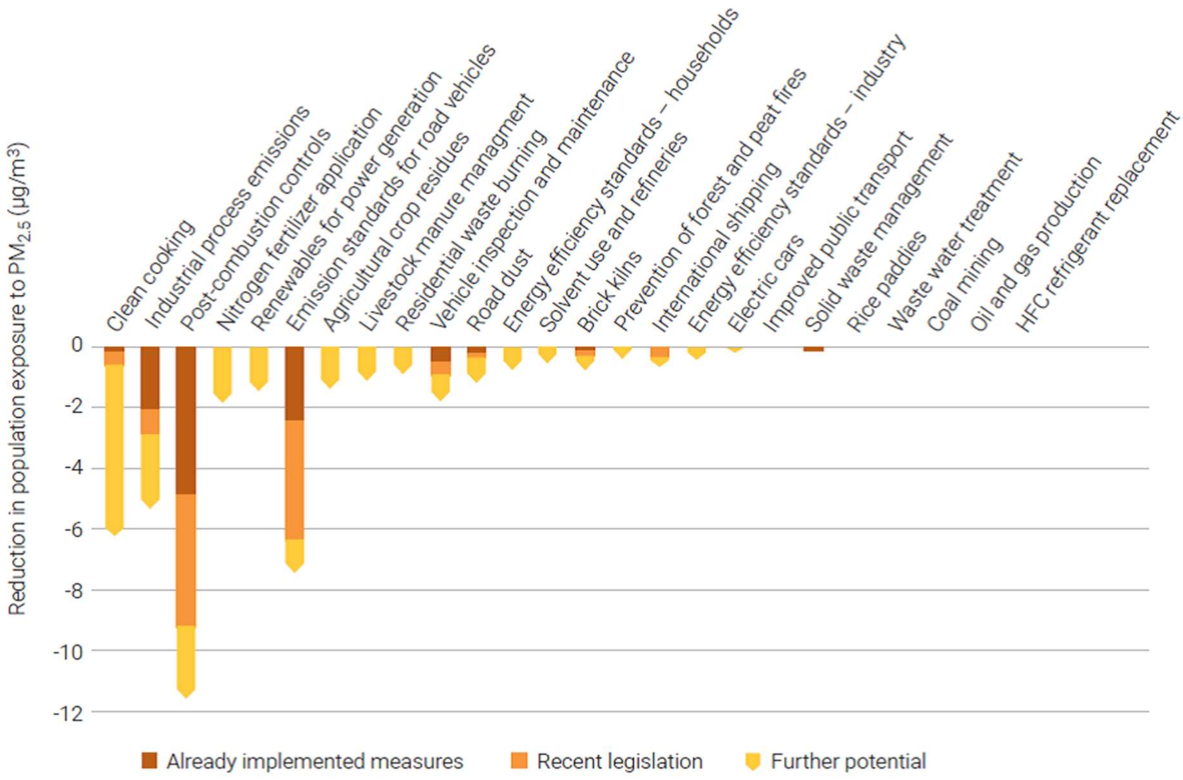



**Figure 8: Impacts on population-weighted exposure to $PM_{2.5}$ in 2030 from implementation of 25 clean air measures, ranked by further potential**

Source: UNEP (2019b).

Interactions between sectors need to be considered alongside potential impacts to environmental sinks. Likewise sink focused policies, such as air quality, soil, climate, ecosystems, and water are best placed when they identify the risks from sector-based activities with options to mitigate adverse impacts. The UNEP (2019b) advises, in science and policy, that a multi-source, multi-sector perspective will allow synergies and trade-offs to be better understood. In addition, a holistic and integrated and coherent approach is required to address the global challenge of managing nitrogen effectively and efficiently. Moreover 'smart regulation'¸ the use of multiple rather than single policy instruments, and a broader range of regulatory actors, will also produce better regulation outcomes (Gunningham and Sinclair 1998).

## 1.7. What do we know about nitrogen policies?

Nitrogen management is a major international policy issue and international policy actions are easier to track. Less is known about the nitrogen policy landscape at national levels (Kanter et al. 2020a). A limited understanding remains on how many nitrogen-related policies there are, what issues they address, and what types of instruments are used. In addition, how existing policies may inadvertently lead to increases in nitrogen pollution is poorly understood. Policy fragmentation, and the lack of understanding on nitrogen-related policies and their trade-offs are barriers to being able to tackle the nitrogen challenge (Yang et al. 2022). This is one of the challenges that SANH aims to take on.

An initial international assessment attempted to address this knowledge gap by creating the world's first nitrogen policy database. Kanter et al. (2020b) identified 2,726 policies across 186 countries derived from the ECOLEX database and identified the gaps and opportunities in nitrogen policy, around the world. Overall, their analysis revealed that policy integration was limited and ill-equipped to deal with the cross-cutting nature of the global $N_r$ challenge. From South Asia they had identified 56 policies directly relevant to nitrogen valid in 2017.

A comprehensive assessment of nitrogen policy, its management, and scientific aspects to move towards sustainable nitrogen management is urged under the 'Colombo Declaration'. The research undertaken by the SANH contributes directly towards these actions for South Asia through the collection and analysis of nitrogen–related policies from South Asia. The open-access policy database (Yang et al. 2021) provides a valuable resource for South Asia governments and the wider scientific community. In collaboration with SACEP, a regional report for South Asia (SACEP & SANH 2022) was published that provides:

- An overview of current nitrogen emissions and trends, drivers and impacts to explain why sustainable nitrogen management is a globally important issue, as it is for South Asia.
- An assessment of 966 nitrogen related policies, valid in 2019, from South Asia (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka).

In addition, a journal paper titled: 'Policies to combat nitrogen pollution in South Asia: Gaps and opportunities' was published (Yang et al. 2022). The paper assists South Asia policy development by providing new insights into nitrogen-related policies in the region by building on the global analysis and database.

National level nitrogen policy assessments are underway. This report is the first of its kind to provide a national overview on the extent of nitrogen-related policies for Bangladesh. Included in its analysis are indirect policies that may not consider nitrogen in their formulation but potentially have implications anyhow for nitrogen management. By building a better understanding of the current nitrogen policy landscape both at the national and region level, this report supports efforts to develop effective nitrogen management policies for the future.

### 1.8. Nitrogen policy events across the globe and South Asia

Assessing and managing nitrogen sustainably is crucial for achieving the 17 UN Sustainable Development Goals (SDGs) targeted for 2030 (Yang et al. 2022). The UNEP report (2019a) on 'emerging issues of environmental concern' states that nitrogen policies are fragmented, which is apparent, for example, in the Sustainable Development Goals (SDGs). The SDG indicators reveal that nitrogen is ''relevant almost everywhere but barely visible anywhere'. The exception is for the nitrogen related indicator associated with the SDG 14.1 on life below water. Proposals to adopt NUE or N losses into the SDGs have yet to be implemented.

Several international policy events in relation to nitrogen can be linked to activities in South Asia (Figure 10). In 1982, SACEP was established with the mission to promote regional co-operation in South Asia in the context of sustainable development. SACEP, amongst other actions, commissioned UNEP funded research on ''Nutrient loading and eutrophication of coastal waters of the South Asian seas''. SACEP serves as a key mechanism for regional intergovernmental collaborations to tackle nitrogen waste.

The International Nitrogen Institute (INI), established in 2003, is another initiative that has helped catalyse events globally and in South Asia. INI has a core goal to optimize nitrogen's beneficial role in sustainable food production and minimize nitrogen's negative effects (Raghuram et al. 2021). In 2012, the South Asian Nitrogen Centre (SANC) was established as one of the six global INI centres.

The SANC is also part of the Global Partnership on Nutrient Management (GPNM), which forms a partnership of governments, scientists, policy makers, private sector, NGOs, and international organisations to respond to the ‘nutrient challenge’. The GPNM, currently chaired by India, is within the UNEP Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (UNEP/GPA). This partnership has facilitated further research on $N_r$ and led to further initiatives, including the formation of SANH.

The UN Resolution on Sustainable Nitrogen Management (UNEP/EA.4/L.16) has further brought South Asia into global focus, leading to the Colombo declaration, in October 2019. The ‘Colombo Declaration on Sustainable Nitrogen Management’ spearheaded by Sri Lanka with the support of the UNEP outlines an ambition to ‘halve nitrogen waste by 2030’ whilst highlighting the multiple benefits across all the UN SDGs. United Nations member states endorsed a proposed roadmap for action addressing nitrogen challenges. A central part of the ‘Road map for Action on Sustainable Nitrogen Management 2020–2022’ is the establishment of the Inter-convention Nitrogen Coordination Mechanism (INCOM).

In March 2022 UNEA-5.2 was adopted as a new resolution on nitrogen management that builds on UNEA-4. This resolution prepares the way for the second phase of action in the run up to UNEA-6. UNEA-5 encourages member states, amongst other actions, to share information on national action plans.

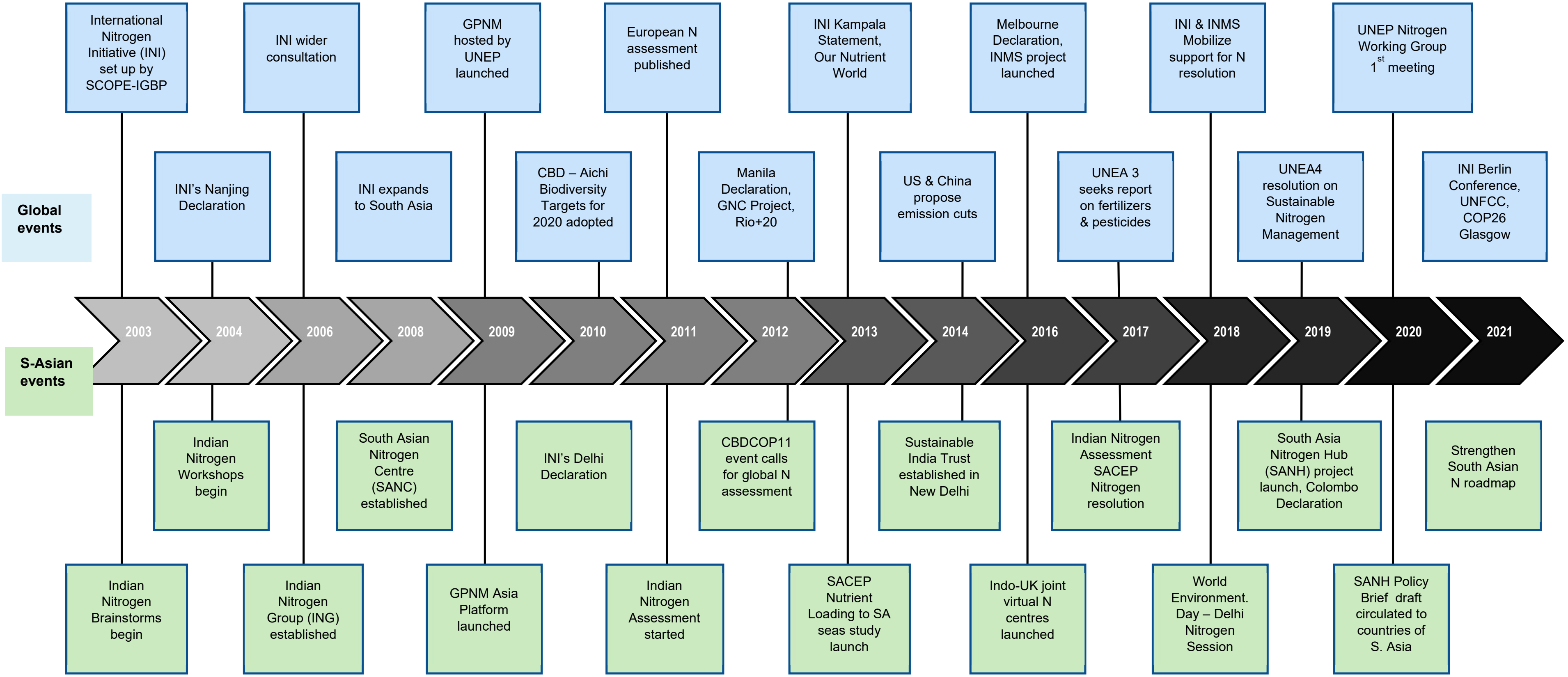



**Figure 9: Timeline of global and South Asian developments toward global cooperation on sustainable nitrogen management**

Source: Raghuram et al. (2021).

# 2. Bangladesh Country Profile and Priorities

## 2.1. Biophysical and socio-economic characteristics

Bangladesh is a country with around 166 million people, located right at the heart of the Ganges-Brahmaputra-Delta in South Asia (UNFPA 2021). The country has a relatively complicated and variegated geography with multiple categories of landscapes (piedmonts, river, tidal and estuarine floodplains, uplifted blocks and hills) combined with environmental hazards (Brammer 2016). Despite being one of the most vulnerable countries to climate change, Bangladesh displayed some remarkable progress in poverty reduction and in meeting internationally set development targets including SDGs. From being among the poorest nations during her birth in 1971, the country has reached lower middle-income status in 2015 and is also on track to graduate from UN's Least Developed Countries (LDC) list in 2026 (World Bank 2021a). Bangladesh has been among the fastest growing economies around the globe with strong ready-made garment (RMG) export sector and stable macroeconomic condition (World Bank 2021a). The service sector dominates the economy in terms of share in GDP, while agriculture dominates the employment sector (although the proportion is decreasing over the year) by employing around 38% of total employment in 2019 (MoF 2021; World Bank 2021c).

### 2.1.1. Geographical characteristics of Bangladesh

Bangladesh lies in the north-eastern part of South Asia and is bounded by India, Myanmar and the Bay of Bengal. The total area of the country is 14,757 thousand hectares (ha), where the limits of territorial water area are 12 nautical miles and the area of the high seas extends to 200 nautical miles. The country primarily consists of plain and fertile land, except some hilly areas in the north-east and south-east and some high land in the northern portion of the country. The main rivers are the Padma, the Jamuna, the Teesta, the Brahmaputra, the Surma, the Meghna and the Karnaphuli with around 230 tributaries and having a total length of 24,140 kilometres (BBS 2021).

**Table 2: Land use and land use changes in Bangladesh**

| Land Use Type | 2010 | | 2020 | |
|---|---|---|---|---|
| | Area ('000 ha) | % | Area ('000 ha) | % |
| Crop land | 9598 | 65 | 8587 | 58 |
| Sundarbans (mangrove) | 427 | 3 | 410 | 3 |
| Reserve forest | 284 | 2 | 130 | 2 |
| Homestead, rivers, urban and others | 4447 | 30 | 5450 | 37 |
| Total | 14756 | 100 | 14757 | 100 |

Source: SRDI (2020).

The total forest area in the country is merely 5% of the country's total land area, though Sundarbans, the world's largest mangrove forest (3%) lies at the southern part of the Ganges delta and is spread across the coastal areas of Bangladesh along with West Bengal of India (BBS, 2021). Bangladesh has experienced land use and land cover change over the years in response to growing population and economic growth, infrastructural expansion and climate change (Xu et al. 2020). Despite the increasing demand of land for non-agricultural purposes, the largest share of area is still accumulated as crop land (58%), but this has decreased by around 7% from 2010 to 2020 (Table 2). Meanwhile, the share of land for homesteads and urbanization has increased from 30% in 2010 to 37% in 2020. The areas occupied by Sundarbans and reserve forest have remained unchanged throughout the time period. Figure 10 depicts the land use status in Bangladesh.

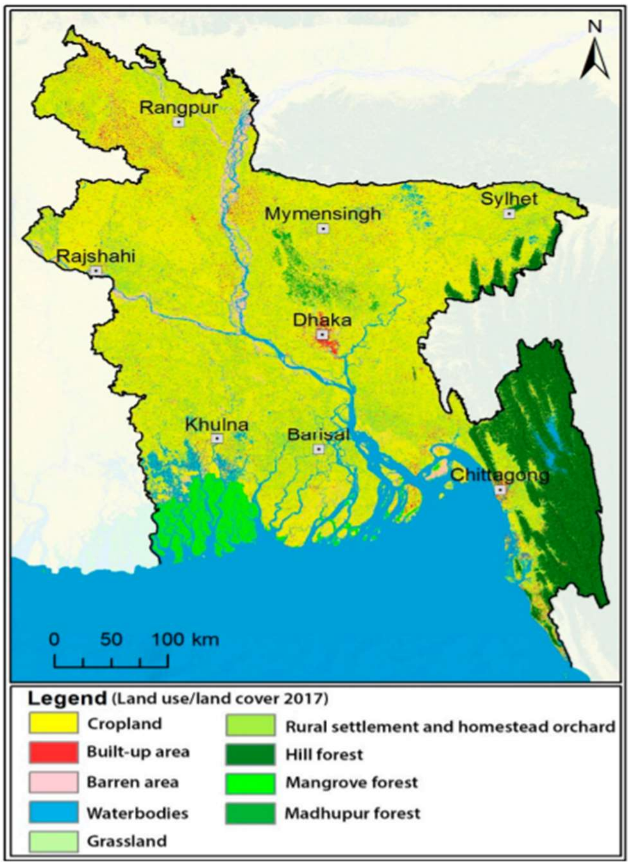



**Figure 10: 2017 land cover map of Bangladesh developed using Landsat 8 and Google Earth Engine**

Source: Uddin et al. (2019).

### 2.1.2. Demographic characteristics of Bangladesh

Bangladesh Bureau of Statistics conducted the fifth decennial population census in the country, according to which the population of the country was around 150 million in 2011 and the intercensal growth rate was about 1.37% per annum (BBS 2021). According to the World Bank (2021b), the population of Bangladesh in 2020 was 164.7 million.

Dhaka is the capital and largest metropolitan city and falls within a monsoon climate zone. Chattogram is the main seaport and second largest metropolitan city of Bangladesh (BBS 2021). According to a labour force survey in 2016-17, the total employed (both formal and informal) population of the country was 63.5 million, among which females were about 20 million and males were about 43.5 million (MoF 2021). Around 0.53 million people from Bangladesh went overseas for employment during 2019-20 and contributed nearly 5.52% of country’s GDP through remittances (MoF 2021).

### 2.1.3. Administrative units

Bangladesh is divided into eight administrative divisions. For the convenience of administration, the divisions are further divided in districts and since the administrative re-organization carried out in 1984 the country has been divided into 64 districts and each district is further divided into sub-districts.

### 2.1.4. Primary sectors and contribution to GDP

The economy of Bangladesh is dominated by the service sector in terms of the share in GDP, as seen from Table 3. It accounted for 51.53% of GDP in 2020-21, relatively lower than in 2015-16 (53.58%), which might be the consequence of employment cuts in the face of COVID-19 (MoF 2021). The Covid-19 pandemic may also explain the decreased GDP growth rate (5.47% in 2020-21) which is the lowest since fiscal year 2008-09. Although the rural economy of Bangladesh (constituting two-third of the country's total population) mostly depends on agriculture (World Bank 2016), its share in GDP has been declining throughout the years (Table 3). Steady expansion of the manufacturing industries, electricity, gas and water supply and construction sector, is further encouraging the growth of the industrial sector (MoF 2021; World Bank 2021a), which contributes to the increasing share of the GDP (Table 3).

**Table 3: Sectoral Share of GDP at constant price**

| Economic sectors | Share of GDP (%) | | |
|---|---|---|---|
| | 2015-16 | 2019-20 | 2020-21 |
| Agriculture including forestry and fishing | 15.35 | 13.74 | 13.47 |
| Industry | 31.54 | 34.78 | 34.99 |
| Services | 53.58 | 51.48 | 51.53 |

Source: BBS (2021, 2016).

Bangladesh is primarily an agrarian country and agriculture accounts for the largest share of employment among all the economic sectors. The agricultural sector constituted about 13.47% share in GDP in 2020-21, within which crops and horticulture, animal farming, fisheries and forestry accommodate for 6.94%, 1.74%, 3.19% and 1.43% respectively. Rice, Jute, potato, vegetables, wheat, tea, and maize are the principal crops of Bangladesh (BBS 2021). Agricultural cropland occupies around 58% of the total land area and these holdings are decreasing in response to main factors including the ever-growing population and urbanisation (BBS 2021). Hence, modern farming techniques and equipment are being frequently used for higher production (i.e., high N-fertilizer use to increase food grain production).

The fisheries sector also plays a vital role in Bangladesh in terms of nutritional security, supplying over 60% of animal protein (Rahman et al. 2022). As fish farming is growing to feed more people, it requires higher amount of fertilizer and supplementary feed. Moreover, only 10-30% of the feed $N_r$ is used by fish, with the remaining 70-90% becoming a potential source of $NH_3$ and $NO_2$ in gaseous form being released into nature (Hu et al. 2012).

Livestock, being another vital sector of the economy, contributes 1.74% of the national GDP, and further releases a substantial quantity of $N_r$ into the environment through fresh manure production (Rahman et al. 2022). Thus, the drive for higher production in each sub-sector of agriculture causes excessive use of inorganic $N_r$ compounds, threatening the sustainability of the environment through reactive nitrogen production.

### 2.1.5. Climate and key vulnerabilities

Bangladesh generally experiences a sub-tropical monsoon climate. Although there are six seasons in a year, summer, winter and monsoon are prominent. During summer, the maximum temperature can reach $37^0$C on average, whereas in some places occasionally it can rise to $41^0$C. Winter is relatively pleasant with temperatures usually ranging from minima of $7^0$C – $13^0$C to maxima of $24^0$C – $31^0$C. The monsoon season starts in July and continues to October. It accounts for around 80% of the total annual rainfall. The annual average rainfall usually varies from 1,429 to 4,338 millimetres (BBS 2021). Complicated geographic features not only make the country prone to natural disasters, but also make climatic vulnerabilities more prominent (FAO 2011). People from the coastal areas of Bangladesh are facing the adversity imposed by increasing salinity, cyclone etc., while the northern population are suffering due to excessive flooding, drought etc. (Hossain et. al. 2012). Bangladesh was identified as one of the most vulnerable countries (ranked fifth in 2011) to climate change in an Action Aid Research Report (Mahmood 2012).

## 2.2. Environmental pollution in Bangladesh

Pollution has become one of the prime concerns for humankind after the industrial revolution of the 19th century that led to environmental disaster (Alam 2009). Current environmental conditions of Bangladesh are not in a very favourable condition as different forms of pollution (such as air, water, soil, and noise) are threatening the ecological and economic balance of the country (Sheraj 2017). The severity of atmospheric pollution in Bangladesh is reflected by the position of Dhaka (the capital and primate city) as the 3rd most contaminated city in the world (Nahar et al. 2021). Environmental pollution (e.g., rapid construction of brick kilns causing an increment of greenhouse gases into the atmosphere) in different forms are adding to the adversity of climate change and its impact e.g., salinity intrusion, which also contribute towards frequent natural disasters e.g., cyclones and river erosion. Figures 11, 12 and 13 show some phenomena related to climate change around Bangladesh.

**Figure 11: River erosion, Lalmohon Bhola**

**Figure 12: Changes in temperature (drought), Satkhira**

**Figure 13: Brick fields polluting the hill tracts, Bandarban**

Source: Mahmood (2012).

## 2.3. Air, water, soil quality

**Air quality in Bangladesh**

Air pollution has emerged as a significant cause of public health issues. In recent years, Bangladesh has ranked among the top polluted countries across the globe (Islam et al., 2020). According to Switzerland based IQAir (2022a), Bangladesh has an average US AQI of 162 in 2020.[6] $PM_{2.5}$ concentration in Bangladesh air is currently 15.4 times above the 2021 WHO annual air quality guideline value (WHO has revised their 2005-ambient air quality guideline and published a new guideline in September, 2021). The Air Quality Management Programme (AQMP) led the Bangladesh government to revise its ambient air quality standards in July, 2005. Table 4 depicts the ambient air quality standards (both WHO and Bangladesh standards) along with the newly developed global air quality guideline by WHO.

**Table 4: Air quality guidelines (AQGs)**

| Pollutants | Averaging time | AQGs, 2005 | Bangladesh standards, 2005 | Averaging time | AQGs, 2021 |
|---|---|---|---|---|---|
| $PM_{2.5}$ µg/m$^3$ | Annual<br>24-hour | 10<br>25 | 15<br>65 | Annual<br>24-hour | 5<br>15 |
| $PM_{10}$ µg/m$^3$ | Annual<br>24-hour | 20<br>50 | 50<br>150 | Annual<br>24-hour | 15<br>45 |
| Ozone ($O_3$) µg/m$^3$ | 1 hour<br>8 hours | <br>100 | 235<br>157 | Peak season<br>8-hour | 60<br>100 |
| Nitrogen dioxide ($NO_2$) µg/m$^3$ | Annual | 40 | 100 | Annual<br>24-hour | 10<br>25 |
| Sulfur dioxide ($SO_2$) µg/m$^3$ | 24- hour<br>Annual | 20 | 80<br>365 | 24- hour | 40 |
| Carbon monoxide (CO) µg/m$^3$ | 8 hours<br>1 hour | 10<br>30 | 10<br>40 | 24-hour | 4 |

Source: WHO (2021) and DoE (2018a).

In Bangladesh, the air quality indicator (AQI) is calculated based on the prevailing concentration of 5 criteria pollutants, PM ($PM_{10}$ and $PM_{2.5}$), $NO_2$, CO, $SO_2$ and $O_3$ (DoE, 2018a). According to Bangladesh government guideline, $AQI \leq 100$ is accepted as good and moderate, whereas $AQI \geq 300$ is considered to be extremely unhealthy.

The Ministry of Environment, Forest and Climate Change of the Government of Bangladesh implemented a Clean Air and Sustainable Environment (CASE) project from 2010 to 2019. The Department of Environment (DoE) component of the project established several continuous air monitoring stations (CAMS) in major cities (Figure 14) and the network encompassed all the regions of the country - Dhaka, Narayanganj, Gazipur in the centre, Chattogram in the south-east, Khulna and Barisal in the south, Rajshahi in the west, and Sylhet in the north-east region of the country. Air Quality Indices (AQI) of the cities are calculated and published online to notify people about air quality, which is still being provided but in a relatively irregular manner.

[6] US AQI is calculated using based on averages of four major air pollutant (Ozone, particle pollution, carbon monoxide and sulfur dioxide) concentrations measured in a full 8 hours or a full day (US EPA, 2018)

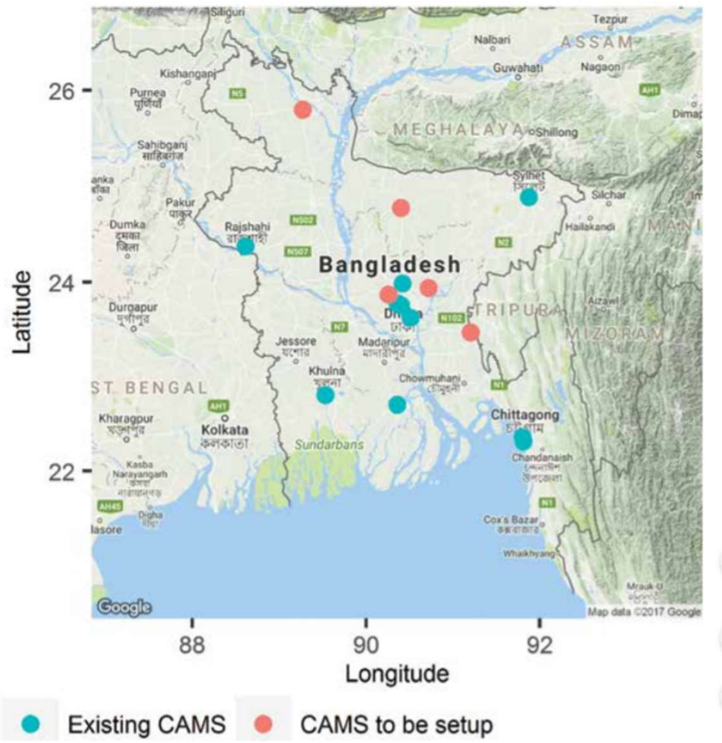



**Figure 14: Locations of existing and future establishment of Continuous Air Monitoring Stations (CAMS), 2018**

Source: DoE (2018a).

Table 5 shows the statistics of AQI in the cities of Bangladesh, in the year 2016 and 2017. The air quality was in a moderate situation for most of the days in almost every city during 2016 and 2017. Dhaka, Gazipur and Narayanganj were the cities had a higher number of days when the air quality was extremely unhealthy (AQI >301) according to Bangladesh guideline. On the contrary, Sylhet was the cleanest among all the cities, having the highest number of days with AQI≤100.

**Table 5: Statistics of air quality index in different cities of Bangladesh, 2016 and 2017**

| Cities | Year | Total Days | No of days with | | | |
|---|---|---|---|---|---|---|
| | | | AQI ≤100 | AQI 101-200 | AQI 201-300 | AQI >301 |
| Dhaka | 2016 | 340 | 148 | 108 | 45 | 39 |
| | 2017 | 359 | 133 | 130 | 23 | 73 |
| Gazipur | 2016 | 344 | 158 | 78 | 50 | 58 |
| | 2017 | 320 | 142 | 80 | 29 | 69 |
| Narayanganj | 2016 | 335 | 165 | 69 | 31 | 70 |
| | 2017 | 348 | 136 | 98 | 34 | 80 |
| Chittagong | 2016 | 316 | 191 | 63 | 31 | 31 |
| | 2017 | 340 | 189 | 96 | 38 | 17 |
| Sylhet | 2016 | 276 | 213 | 51 | 10 | 2 |
| | 2017 | 365 | 220 | 124 | 16 | 5 |
| Khulna | 2017 | 139 | 79 | 40 | 16 | 4 |
| Rajshahi | 2016 | 315 | 154 | 115 | 32 | 14 |
| | 2017 | 338 | 158 | 122 | 39 | 19 |
| Barisal | 2016 | 323 | 171 | 84 | 47 | 21 |
| | 2017 | 343 | 168 | 106 | 37 | 32 |

Source: DoE (2018a).

Islam et al. (2020) also found such spatial differences in air quality between Dhaka and Sylhet. They also mentioned about the seasonal pattern of air quality and suggested extremely unhealthy and very unhealthy air in January-March in 2020. The presence of various modes of transport in larger amounts and rapid growth of industries causes pollution to be greatest in big and central cities like Dhaka, rather than in smaller cities. The air was seemingly clean in Khulna city, but the result is inconclusive and patchy, since it contained information for only 139 days.

Air pollution can occur through both point and non-point sources. The United States Environmental Protection Agency (EPA) defines point source pollution as any contaminant that enters the environment from an easily identified and confined place (National Geographic Society 2019). For example, factories and power plants can affect the air and can be easily identified as point sources of pollution. Moreover, smokestacks can emit carbon monoxide (CO), nitrogen dioxide ($NO_2$), heavy metal or particulate matter into the air. Non-point source pollution can be defined as the opposite of point-source pollution, with the pollutants being spread over a wide area. Airborne pollutants are prime contributors to acid rain that can result from the vast movement of the pollutants from many factories and power plants, and they are considered nonpoint-source pollution (National Geographic Society 2019).

Industrial and vehicular emissions are the two major sources of air pollution in Bangladesh, particularly in urban areas (i.e., Dhaka, Gazipur, Narayanganj etc.). Industrial emission sources like thousands of ready-made garment factories (RMG), chemical industries, tanneries in Hazaribag in Dhaka etc. and the number of vehicles is increasing at alarming rates (Kudrat-E-Khuda 2020; Begum et al. 2013; Alam 2009). Combustion of fuels in motor vehicles not only produces fine particle pollution directly but also emits $NO_x$ and $SO_x$, which can lead to the production of further PM in the atmosphere (DoE 2012a). Moreover, $NO_x$ and $SO_x$ react with $NH_3$ (which is also abundant in Bangladesh due to its large agricultural sector) and produces fine particles of $NH_4$, $NO_3$ and $NH_4SO_4$ (DoE 2012a).

The Norwegian Institute for Air Research (2014) also mentioned mobile sources (different types of vehicles) as major sources of $NO_x$ in Dhaka (59% of total annual $NO_x$ emissions) and Chattogram (42% of total annual $NO_x$ emissions). The distribution of $NO_x$ emissions categorized into different sources in 2013 can be observed in Figures 15 and 16. Diesel-powered vehicles as well as CNG and gasoline-powered vehicles emit high $NO_x$ in the atmosphere. The industrial sources emit around 16% of $NO_x$ in Dhaka. While fossil fuel constituted around 22% of total $NO_x$ emission in Chattogram, it was found to be insignificant as an emission source in Dhaka. Use of wood, straw etc. for cooking in many locations, more specifically rural areas of Bangladesh cause such $N_r$ pollution. While in case of PM concentration Brick kiln held the highest share (91% of total annual $PM_{10}$ and 84% of total annual $PM_{2.5}$ emission) in Dhaka (NILU, 2014). Bangladesh government has taken action e.g., banned the use of FCKs (Fixed Chimney Kiln) in order to reduce emissions from brick kilns (DoE 2018a).

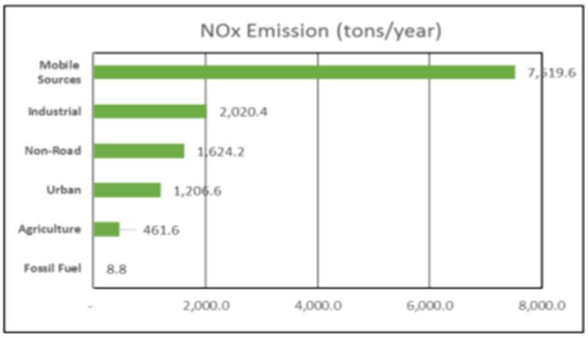



**Figure 15: $NO_x$ Emissions from Different Sectors in Dhaka, 2013**

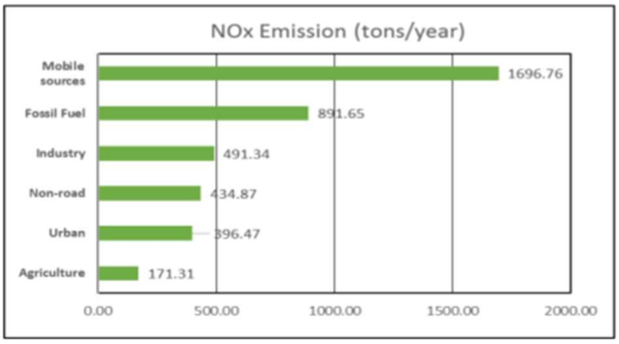



**Figure 16: $NO_x$ Emissions from Different Sectors in Chattogram, 2013**

Source: NILU (2014).

Vehicle emissions are one of the critical factors of air pollution, especially in Dhaka city where 40% of imported cars are registered (DoE 2017). The government of Bangladesh has taken many measures to control this pollution through vehicle emission (e.g., phasing out the 2 stroke-3 wheeled baby taxis in 2003 and revision of vehicle emission standards in 2005). Begum et al. (2012) mentioned a 41% decrease in the $PM_{2.5}$ concentration in Dhaka as a result of that phase-out of baby taxis. Such steps have kept the air quality in Dhaka city liveable in the face of massive increase in vehicle number along with other pollution sources (e.g., brick kilns and construction).

**Water Quality**

The importance of water for the survival of any living being highlights the responsibility of proper monitoring and maintenance of water quality (for consumption or external use). There are about 230 rivers in Bangladesh, altogether covering about 7% of the surface area (BBS 2020). Out of 57 trans-boundary rivers, 54 are shared with India and 3 with Myanmar. With progressing technical advancement and increasing population, industrial dumping, household and municipal waste, medical waste, and agricultural run-off etc. are increasing into water courses and further degrading the surface water quality (DoE 2017). Furthermore, nitrogen is essential for agriculture but more than half of the nitrogen fertilizer can be leached into water. Excessive nitrogen in water may cause hypoxia and dead zones, problems caused from shortages of dissolved oxygen in water (Damania et al. 2019). Concerned over the severe pollution, the Bangladesh government has already declared four rivers (Buriganga, Shitalakhya, Turag and Balu) as Ecologically Critical Areas (ECA) to protect them from further pollution (DoE 2017).

The Department of Environment in Bangladesh had reported (DoE 2017) water quality analyses of 10 major rivers in Bangladesh for the years 2010 and 2016. These rivers are in association with major industrialized cities like the Buriganga in Dhaka, the Shitalakhya in Narayanganj and the Turag in Gazipur, and all are severely polluted. There is a high level of water contamination through industrial emissions of heavy metals, e.g., iron (Fe), nickel (Ni) and substances like ammonia ($NH_3$), ammonium ($NH_4^+$), and sulphate ($SO_4$). Other rivers are in relatively better condition (far from cities and industrial build-ups) but not completely risk free (facing increasing agricultural run-off).

During 2010 and 2016, the pH values of all the major rivers were within EQS (Environmental Quality Standard) for both seasons but variation was observed in terms of DO (Dissolved Oxygen) and BOD (Biochemical Oxygen Demand) (Table 6). Direct discharge of untreated effluent from industries, tannery waste, domestic waste, and medical waste etc. were the proximate cause for the depletion of DO from the required level in the Buriganga, Shitalakhya and Turag rivers in both dry and wet seasons. The exception was for Shitalakhya (DO- 5.5 mg/l) in the wet season during 2010, but by 2016 it had also degraded. BOD content was higher than EQS for Buriganga irrespective of the seasons, while for Shitalakhya it was below EQS and in terms of Turag River BOD turned worse than 2010 (Table 6).

Expansion of the textile and tannery industries near these rivers has a detrimental impact on surface water. Textile dyeing effluent contains higher pH, $NO_2$ and $NO_3$, which further cause the imbalance in DO and BOD. Use of water for textile dyeing also depletes the groundwater level and adversely affect the aquatic ecology. The Dhaleshwari, Brahmaputra and Mathavanga rivers were found to be of better quality as the measures were within the EQS level for both seasons. The only exception was for the Dhaleshwari river in case of DO (2.8 mg/l) content in dry period during 2016, which was much lower than the EQS level indicating increased pollution over time.

**Table 6: Level of different parameters of water quality in major rivers of Bangladesh**

| Major River | Dry season (November - April) | | | | | | Wet season (May - October) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | | DO | | BOD | | pH | | DO | | BOD | |
| | 2010 | 2016 | 2010 | 2016 | 2010 | 2016 | 2010 | 2016 | 2010 | 2016 | 2010 | 2016 |
| Buriganga | 7.3 | 7.3 | 0.5 | 0.2 | 26.4 | 17.1 | 7.3 | 7.3 | 3.8 | 3.0 | 8.2 | 6.5 |
| Shitalakhya | 7.3 | 7.3 | 3.8 | 4.3 | 9.6 | 20.0 | 7.3 | 7.3 | 5.5 | 4.1 | 4.7 | 5.5 |
| Turag | 7.3 | 7.3 | 0.0 | 0.4 | 30.9 | 30.5 | 7.3 | 7.3 | 3.7 | 4.5 | 9.5 | 4.8 |
| Dhaleswari | 7.3 | 7.3 | 5.4 | 2.8 | 2.9 | 5.0 | 7.3 | 7.3 | 6.2 | 6.1 | 3.4 | 2.4 |
| Brahmaputra | 7.3 | 7.2 | 5.4 | 7.1 | 4.5 | 1.7 | 7.3 | 7.5 | 5.6 | 6.4 | 2.4 | 1.6 |
| Halda | 7.1 | 7.2 | | 6.7 | | | 7.0 | 7.0 | | 7.2 | | |
| Moyuri | 7.6 | 7.7 | 0.4 | 1.6 | 26.5 | | 7.5 | 7.7 | 2.3 | 2.0 | 5.7 | |
| Surma | 7.5 | 7.2 | 6.3 | 6.1 | 1.2 | 26.5 | 7.5 | 7.1 | 6.8 | 6.6 | 1.2 | 26.9 |
| Korotoa | | 6.8 | | 2.6 | | 5.7 | | 7.4 | | 2.6 | | 6.1 |
| Mathavanga | 7.5 | 7.7 | 2.1 | 5.2 | 4.1 | 0.8 | 7.6 | 7.5 | 3.6 | 5.2 | 2.9 | 0.8 |

Note: EQS (Environmental quality Standard) for fisheries set by government, -pH: 6.5-8.5; DO (Dissolved Oxygen): ≥ 5 mg/l; BOD (Biochemical Oxygen demand): ≤ 6 mg/l.
Source: DoE (2017).

**Sources of Water pollution**

Water quality degradation or water pollution around the globe, primarily adheres towards human activities. The significant ones are unmanaged disposal of mechanical, civil and household wastes in water bodies (Azizullah et al. 2011). The main sources of water pollution can be viewed as point and non-point sources, where point sources incorporate release from metropolitan sewage, treatment plant etc. (Figure 16) and relatively easy to measure and control. On the contrary non-point sources are hard to trace and control. Agricultural movement can be considered as a major non-point source incorporating the utilization of nitrogen compost, mineralization of soil nitrogen etc. (Arefin and Mallik 2018).

**Table 7: Common point and non-point sources of water pollution**

| | |
|---|---|
| Point Source | • Wastewater effluent (Municipal and industrial)<br>• Runoff and leachate from waste disposal site<br>• Runoff and inflation from animal feedlots<br>• Runoff from mines, oil fields, unsewered industrial sites<br>• Storm sewer outfall from cities of population <100000<br>• Overflow of combined storms and sanitary sewers<br>• Runoff of construction sites > 2ha |
| Non-point Source | • Runoff from agriculture (including return flow from irrigated agriculture)<br>• Runoff from pasture and range<br>• Urban runoff of un-drained and drained areas of population <100000<br>• Septic tank leachate and runoff from septic system<br>• Runoff from construction sites <2ha<br>• Runoff from abandoned mines<br>• Atmospheric deposition over a water surface<br>• Activities of land that generate contaminates such as logging<br>• Wetland conversion, construction and development of inland waterways |

Source: Arefin and Mallik (2018).

**Soil Quality**

The greater part of Bangladesh lies within the delta of the combined Ganges-Brahmaputra-Meghna River system and is endowed with fertile soils. More than 85% of the area is flat alluvial plain crisscrossed by rivers and their numerous tributaries and distributaries. Despite being a small country Bangladesh has rich diversity in soil types and the variation is primarily due to the physiography and partly to microclimatic variations. Although most of the country's soil is developed on alluvial deposits, there are hilly formations and evergreen and/or deciduous forest vegetation. Considering the variable characteristics of soil, the entire nation has been divided into seven physiographic units (Figure 17) e.g., Madhupur tract consists of red-brown terrace soil, while Barind tract has grey terrace soil and deep red brown soil or hill tract consisting of brown hill soil. (Huq and Shoaib 2013).

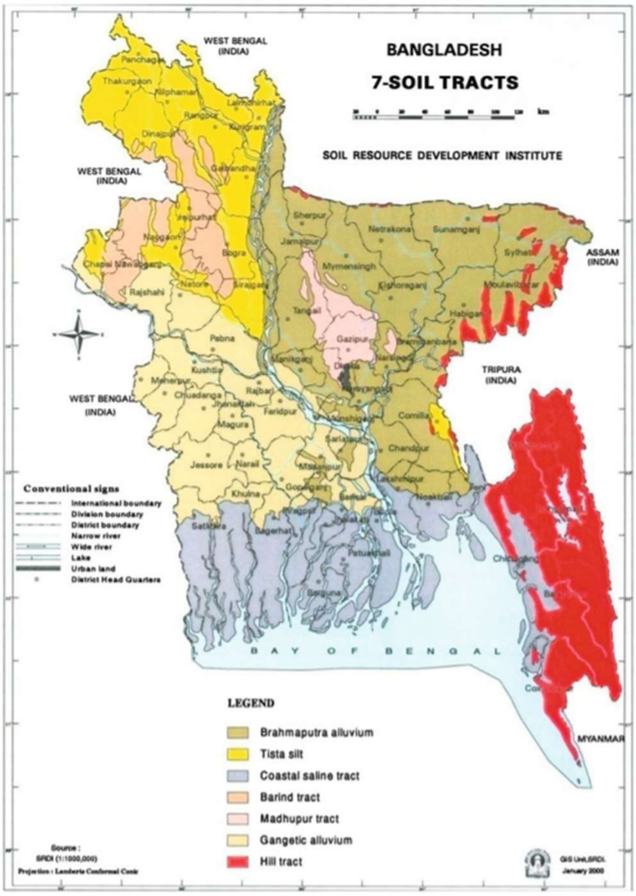



**Figure 17: The Soil Tracts of Bangladesh**

Source: Huq and Shoaib (2013).

Although the soil in Bangladesh is fertile and favourable for agricultural production, gradual changes in soil fertility are being observed in response to land use and management practices. In general, soils are deficient in organic matter and nitrogen. As a response to this problem, the increased use of chemical fertilizers to incorporate nitrogen into the soil is further causing soil and water pollution and also resulting in lower soil fertility (SRDI 2019). Bangladesh is one of the countries with the highest quantity of excess $N_r$ on agricultural land (West et al. 2014). Agricultural $N_r$ use increased to 1,327,760 tonnes in 2019 from 995,852 tonnes in 2000 in Bangladesh (FAOSTAT 2022). Despite several policies focusing on sustainable agriculture (e.g., the National Organic Agriculture Policy 2016), agricultural use of all chemical fertilizers has increased over time; e.g., the use of urea fertilizer in Agriculture has increased by 11.7% since 2002 (Table 8).

**Table 8: Amount of N nutrient and different chemical fertilizers used in Bangladesh agriculture, 2000-2019**

| Year | Agricultural use of $N_r$ nutrient ('000 tonnes) | Fertilizer use in Bangladesh agriculture ('0000 tonnes) | | | |
|---|---|---|---|---|---|
| | | Urea | DAP | MOP | Superphosphate above 35% |
| 2000 | 995.9 | | | | |
| 2001 | 1054.2 | | | | |
| 2002 | 1079.1 | 224.72 | 25.19 | 26.32 | 38.16 |
| 2003 | 951.3 | 200.88 | 11.85 | 27.85 | 39.28 |
| 2004 | 954.0 | 201.33 | 10.10 | 27.15 | 41.35 |
| 2005 | 993.3 | 205.44 | 17.60 | 40.73 | 39.49 |
| 2006 | 1098.9 | 229.69 | 12.52 | 20.81 | 43.03 |
| 2007 | 1048.5 | | | | |
| 2008 | 1287.0 | 276.30 | 8.90 | 27.40 | 14.06 |
| 2009 | 1156.1 | 248.72 | 3.60 | 23.40 | 32.20 |
| 2010 | 1166.8 | 245.51 | 18.10 | 31.90 | 45.20 |
| 2011 | 1274.8 | 265.20 | 30.50 | 48.20 | 56.40 |
| 2012 | 1129.8 | 229.60 | 40.90 | 61.30 | 0.00 |
| 2013 | 1111.7 | 224.70 | 43.40 | 57.10 | 65.40 |
| 2014 | 1230.3 | 246.20 | 54.30 | 57.70 | 68.50 |
| 2015 | 1320.9 | 263.80 | 59.70 | 64.00 | 72.20 |
| 2016 | 1172.3 | 229.10 | 65.80 | 72.70 | 73.00 |
| 2017 | 1240.4 | 242.70 | 68.90 | 78.90 | 70.70 |
| 2018 | 1330.6 | 259.40 | 76.30 | 72.40 | 78.10 |
| 2019 | 1327.8 | 251.00 | 96.20 | 71.60 | 69.10 |

Source: FAOSTAT (2022).

Salinity intrusion is another problem in soil management. Although water and soil salinity are common phenomena in the coastal areas, with gradual climate change it is getting worse and imposing a major constraint in land management of coastal Bangladesh (SRDI 2019).

Soil is undoubtedly a dynamic resource for humans and is also a key receiver of multiple pollutants like hazardous elements (Luo et al. 2007). Currently, contamination of hazardous elements into soil (particularly of urban soil, sourced from industrial emissions, coal and fuel combustion, vehicle emissions etc.) has become a major environmental issue all over the world (Karim et al. 2014). Bangladesh is no exception and cannot escape the deterioration of soil biology and function in the face of such contamination. Land in rural areas of the country are being harmed mostly through fertilizer overdose. Meanwhile, in urban areas, more specifically soil in Dhaka city, is facing serious threats from pollution caused by rapid expansion and industrialization (Islam et al. 2015). Several studies also reported higher concentration of hazardous elements, e.g., heavy metal in urban agricultural soils in Bangladesh (Islam et al. 2015; Rahman et al. 2012). Table 9 depicts a brief overview of environmental pollution along with some incidences of such events in Bangladesh.

**Table 9: Categories of pollution**

| Categories of pollution | Major causes | Major sources | Major impact | Examples (like, areas) |
|---|---|---|---|---|
| Air pollution | Smoke, Dust, toxic substances ($NO_x$, $N_2O$, $SO_2$ etc.), fumes etc. | Industries, transport, biomass burning etc. | Diseases like; Asthma, Brochities, Acid rain etc. | • Brick Kilns use fossil fuel all over Bangladesh<br>• Value added industries like textile, garments, fertilizer and chemical industries in Gazipur, Narayanganj |
| Water Pollution | Municipal and medical waste, industrial discharge, toxic substance like; fertilizer and pesticide mixed with water etc. | Industries, modern farming, water transport etc. | Water borne disease, shortage of drinking water, poisoning and odours etc. | • Poisonous and polluted water in Buriganga river in Dhaka due to tanneries and industrial waste<br>• Chemical fertilizers, pesticides etc. are polluting the nearby waterbodies through agricultural runoff. |
| Soil pollution | Arsenic, heavy metals (agro-chemicals) | Farming (pesticide, chemical fertilizers) | Infertile soil | Drive for higher crop production is causing greater use of chemical fertilizer (i.e., Urea for rice production in Bangladesh) |
| Sound pollution | Construction work, road traffic, rail, aircraft etc. | Transport, industries, food commercials etc. | Discomfort, hearing issues, headache etc. | Heavy traffic in major cities like Dhaka, Chattogram, Bogura |
| Noxious odours | Exhaust fumes, sanitation facilities, water contamination etc. | Waste and wastewater, industrial sewage, agriculture (farm residues) | Discomfort, bacterial and viral diseases, dizziness | • Sewage in the Buriganga river, Dhaka.<br>• Industrial drainage and sewage system in cities like, Gazipur, Dhaka, Narayanganj. |

Source: Developed based on the studies conducted by Briggs (2003) and Alam (2009).

# 3. Nitrogen Emission Trends, Drivers and Impacts in Bangladesh

## 3.1. A brief note about data and its sources

The acceptability of any research is intimately related to the quality and reliability of data used. The related challenges are more critical for environmental researchers, since they face data constraints more regularly than their peers working in many other fields. Most of the available data are estimated and do not go beyond a specific sector or sink, particularly when one searches for time series data at the national level, which was the case for Bangladesh also.

$N_r$ emission data were sourced from EDGAR, the Emissions Database for Global Atmospheric Research developed by the Joint Resource Centre (JRC). EDGAR provides independent estimates of emissions compared to those reported by European Member States or by Parties under the United Nations Framework Convention on Climate Change (UNFCCC), using international statistics and a consistent IPCC methodology. SANH selected EDGAR as the common data source for $N_r$ emissions to enable comparability and consistency across our analyses of the eight SA countries.

These data provide an overview of $N_r$ emissions only. 'Emissions' refers to the production and discharge of substances into the air, especially pollutants as gas. However, $N_r$ enters the environment by a variety of sources and states, not only as atmospheric emissions but also through soils and water. For this report we assess, in the absence of other nationwide data of other sinks, emission trends, which reflects directly to the environmental sinks, air and climate, but also indirectly, due to nitrogen cascades, to other sinks (Galloway et al. 2003). Another point to bear in mind is that the environment responds to the different $N_r$ compounds in different ways. $N_r$ enters the environment by a variety of sources and states, not only as atmospheric emissions but also through soils and water.

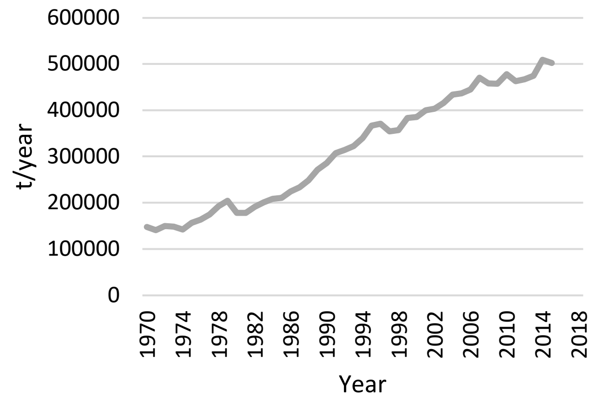
## 3.2. National changes in emissions of key reactive nitrogen compounds

Table 10 reveals that all three key reactive nitrogen compounds; ammonia ($NH_3$), nitrogen oxide ($NO_x$) and nitrous oxide ($N_2O$) have increased over time. The highest change occurred in case of $NO_x$ emissions, which have increased by 228% from 2000 to 2015, whereas there was almost an equal percentage of change in terms of $NH_3$ and $N_2O$ emission in this time period (30-31%). $NO_x$ emissions are likely increasing at this rapid rate due to technological advance leading to high industrial and vehicle emissions (Alam 2009). $NO_x$ is the fastest growing and the largest in terms of total emissions in 2015 (519 Gg), closely followed by $NH_3$ (502 Gg). $N_2O$ emissions were comparatively lower (86 Gg).

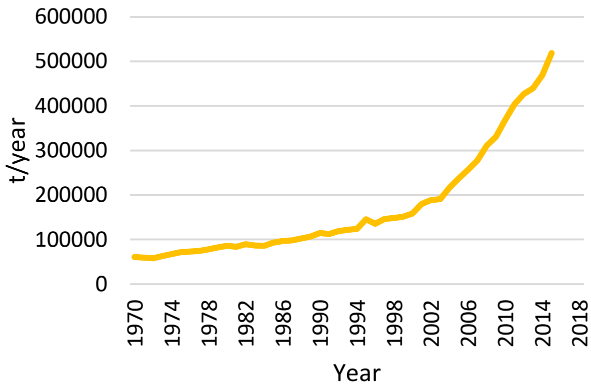
**Table 10: National Changes in emissions of key reactive nitrogen compounds, 2000-2015 for Bangladesh**

| Bangladesh | 2000 | 2015 | % Change |
|---|---|---|---|
| Ammonia - $NH_3$ emissions (Gg/year) | 385 | 502 | 30 |
| Nitrogen oxides - $NO_x$ emissions (Gg/year) | 158 | 519 | 228 |
| Nitrous oxide - $N_2O$ emissions (Gg/year) | 65 | 86 | 32 |

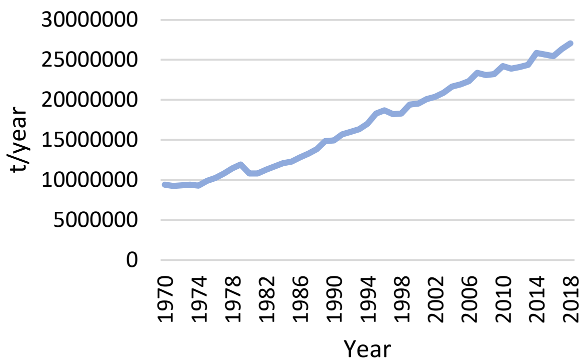
Source: Crippa et al. (2019a, 2019b).



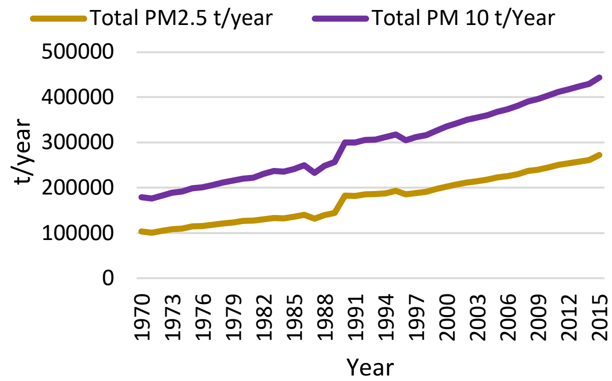

**a) Total ammonia ($NH_3$)**




**b) Total nitrogen oxides ($NO_x$)**




**c) Total nitrous oxide ($N_2O$)**




**d) $PM_{2.5}$ and $PM_{10}$**

**Figure 18: Bangladesh emission trends for ammonia ($NH_3$), nitrogen oxides ($NO_x$), nitrous oxide ($N_2O$) and $PM_{2.5}$ and $PM_{10}$ from 1970 until 2015/2018.**

Source: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a) and EDGAR v5.0 Greenhouse Gas Emissions sourced by Crippa et al (2019b).

In Bangladesh, over the last three decades, all three $N_r$ compounds have been increasing as indicated in Figure 18. $NH_3$ and $N_2O$ have been steadily increasing from 1974 to 2014/2018. The same trends are visible for the particulate matters, $PM_{2.5}$ and $Pm_{10.}$ These results highlight that current policy efforts so far have not been able to mitigate or reduce $N_r$ emissions. These will continue to deteriorate unless further action is taken at the international, national and local levels.

### 3.3. Bangladesh $N_r$ emission trends and sector sources

The total $N_r$ emissions produced by sectors highlight where action is needed to address the main sources. Yet those sectors that have had steep rises in emission over the last decade show 'emerging areas' where action is needed to reduce $N_r$ emission to avoid further harm to people's health and the environment. This section analyses the drivers/sources of $N_r$ emission in Bangladesh and compares the changes in emission levels.

#### 3.3.1. Ammonia ($NH_3$) emissions

Ammonia ($NH_3$) emissions have increased by 55% (4.72 to 263.45 Gg) from 1961 to 2019. Agriculture is by far the largest contributor of $NH_3$ (85%) to the overall total in 2015 and over the last few decades (Figures 19 and 20). The production of $N_r$ and its emissions have risen substantially with higher rates of $N_r$ fertilizer application but low use efficiency (Rahman et al., 2022). These results are similar to the regional results in that total $NH_3$ emissions have increased for South Asia and agriculture (including livestock) was found to be major contributor to these emissions (Yang et al. 2022). The second largest contribution for $NH_3$ emissions was from buildings at 13%, which includes small scale non-industrial stationary combustion, whereas for the category 'other' emission and 'other industrial combustion' contributions were relatively small (1%).[7]

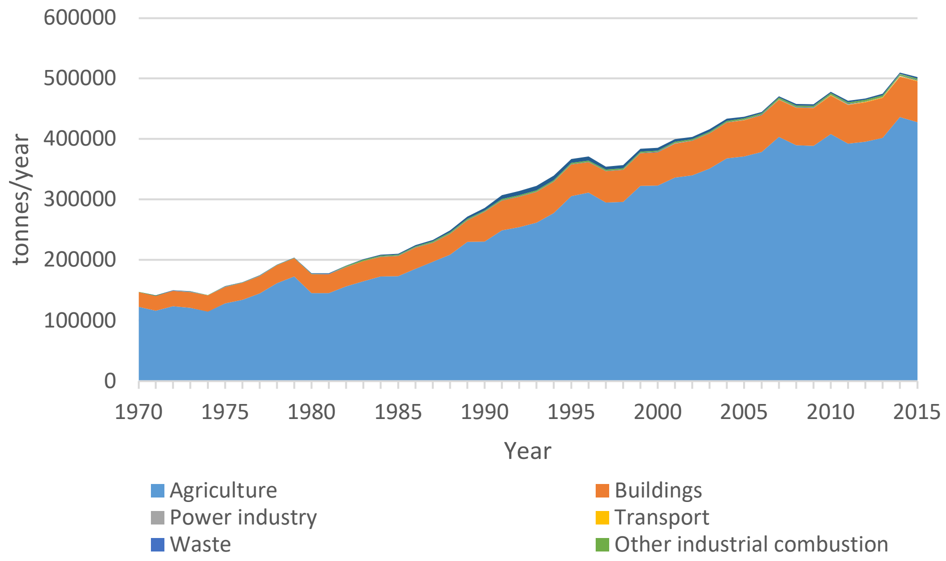



**Figure 19: Trend in the $NH_3$ emission by sectors 1970-2015 in Bangladesh**

Source: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a).

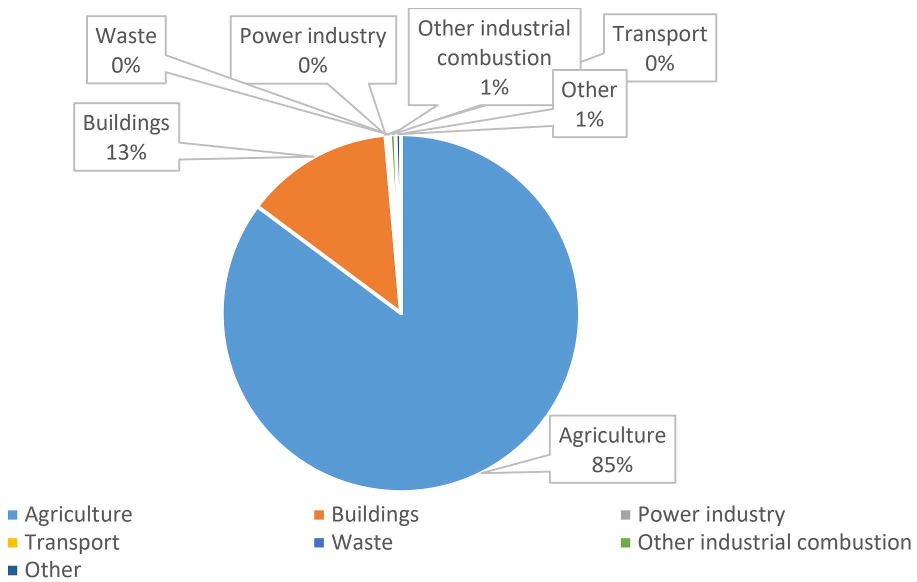



**Figure 20: Ammonia ($NH_3$) emissions by sector for Bangladesh in 2015**

Source: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a).

Sector sources for ammonia emissions have changed to various extents. For almost all sectors, emissions increased from 2000 to 2015 (Table 11). Yet the biggest change has been for transport (4660%) and power (299%) despite small overall contributions to $NH_3$ emissions, these indicate fast

[7] Other industrial combustion includes combustion for industrial manufacturing and fuel production

growing sector emission changes.[8] The only category that saw a reduction in that time period was for 'other' sectors (-47%). Agricultural emissions of $NH_3$ were the highest in 2015 (at 427,852 tonnes) and had increased by 32% between 2000 and 2015.[9]

**Table 11: Ammonia ($NH_3$) emission change for different sectors between 2000 and 2015, in Bangladesh (Tonnes)**

| Year | Agriculture | Buildings | Power industry | Transport | Waste | Other industrial combustion | Other | Total |
|---|---|---|---|---|---|---|---|---|
| 2000 | 322938 | 55018 | 60 | 19 | 650 | 2029 | 4567 | 385281 |
| 2015 | 427852 | 67465 | 239 | 924 | 820 | 2473 | 2439 | 502212 |
| % change | 32 | 23 | 299 | 4660 | 26 | 22 | -47 | 30 |

Source: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al. (2019a).

Sub-sector results (see Appendix Table 1) provide a more detailed breakdown of the sector sources. Under agriculture, this reveals that 'direct emissions from managed soils' are the main emission source (301 Gg in 2015), followed by 'other sectors, and then 'Manure Management' and 'Urea application'. The percentage increase of the sub-sectors between 2000 and 2015 are also illustrated in Appendix Table 1.

### 3.3.2. Nitrogen oxides ($NO_x$) emissions

In contrast to ammonia ($NH_3$), for nitrogen oxides ($NO_x$) agriculture is not the major contributor to overall emissions. The power industry and transport are the two major contributors since 2005. These results match the regional results for South Asia (see Figures 21 and 22). The power industry in 2015 contributed 43% of the total nitrogen oxides ($NO_x$) emissions in Bangladesh. This was followed by transport (25%), other industrial combustion (15%), agriculture (10%) and buildings (7%).

[8] Transport includes road transport, non-road transport, domestic aviation and inland waterways for each country. International shipping and aviation also belong to this sector yet are presented separately due to their international feature.
[9] Other sectors include industrial process emissions (non-metallic minerals, non-ferrous metals, solvents and other product use, chemicals), agricultural soils (urea fertilisation and lime application) and waste.

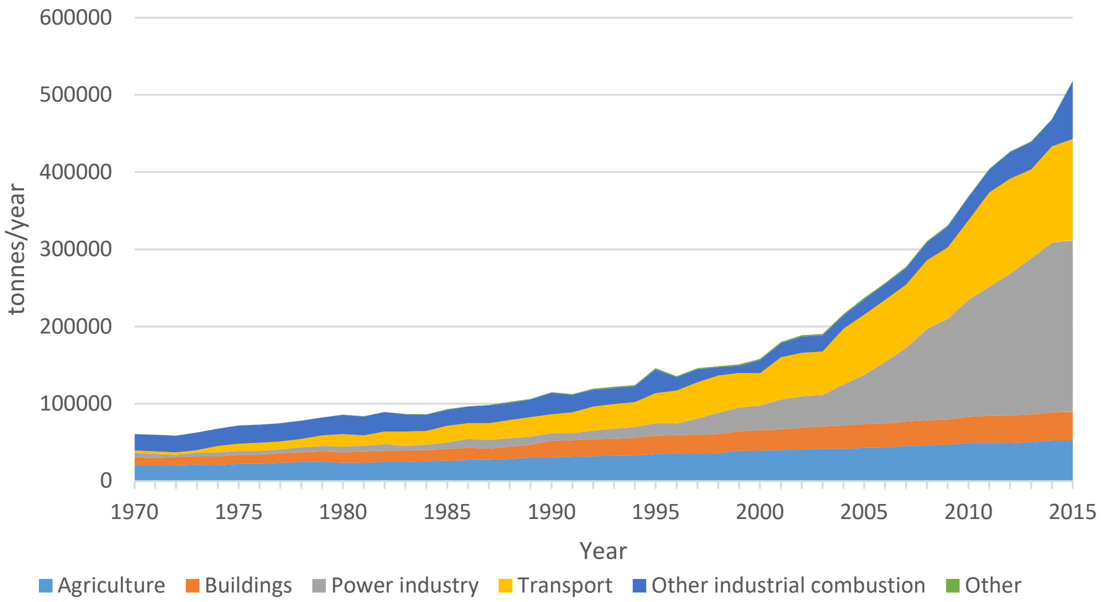



**Figure 21: Trend in $NO_x$ emissions by sectors 1970-2015 in Bangladesh**

Source: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a).

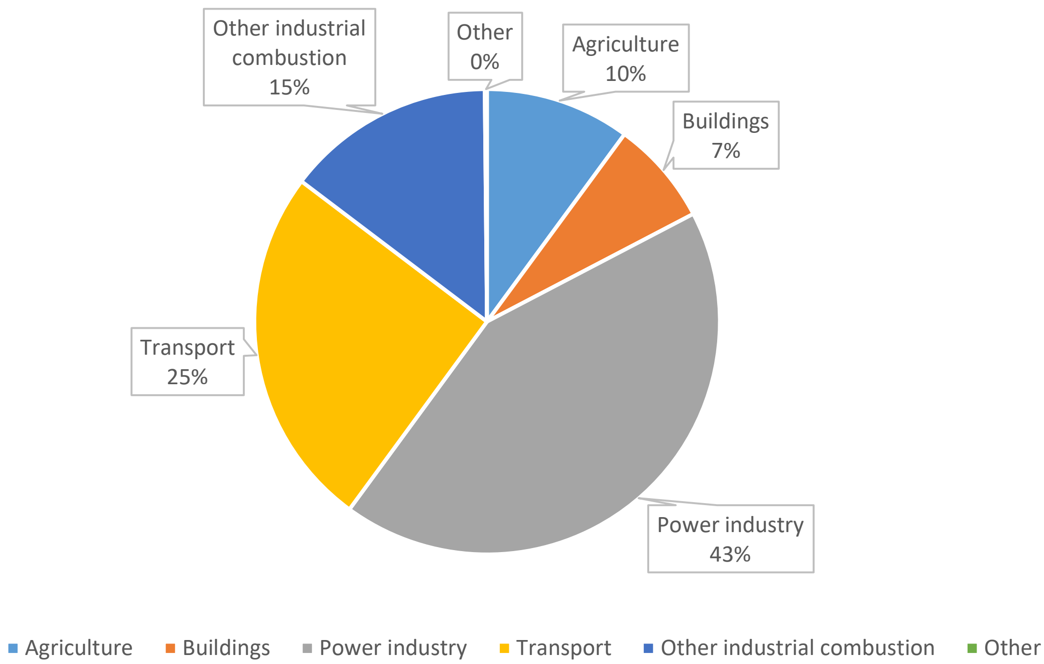



**Figure 22: Nitrogen oxides ($NO_x$) emissions by sector for Bangladesh in 2015**

Source: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a).

Nitrogen oxide ($NO_x$) emissions from agriculture have remained fairly steady over the last three decades. In contrast the sectors that have increased the most between 2005 and 2015 are for the power industry (86%) and other industrial combustion (77%), followed by transport (68%). All sectors increased from 2005 with the exception of the category 'other' (-90%). Since the power, transport and other industrial combustion sectors have the highest contributions and increases in $NO_x$ emissions, this would indicate these sectors as high priority areas of action when tackling $NO_x$ emissions.

**Table 12: Nitrogen oxides ($NO_x$) emission percentage change for different sectors between 2000 and 2015, Bangladesh (tonnes/year)**

| Year | Agriculture | Buildings | Power industry | Transport | Other industrial combustion | Other | Total $NO_x$ |
|---|---|---|---|---|---|---|---|
| 2000 | 39647 | 25870 | 32096 | 41963 | 16999 | 1543 | 158118 |
| 2015 | 52259 | 37647 | 221908 | 130972 | 75389 | 812 | 518987 |
| % change | 32 | 46 | 591 | 212 | 343 | -47 | 228 |

Source: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a).

In the sub sector breakdowns (Table 12) $NO_x$ 'electricity and heat production' has undergone the highest change (591%) relative to other sectors between 2000 and 2015. Electricity and heat production is also the largest contributor to overall $NO_x$ emissions in 2015 (42%), highlighting a priority sector where $N_r$ mitigation is particularly important. Manufacturing industries and construction, road transportation, railways, and waterborne navigation have also had high increases (>147%) since 2000 to 2015 and contribute to overall emissions (16-3%) and represent other sub sectors that should be prioritised. Sub-sector results (see Appendix Table 2) provide a more detailed breakdown of the sector sources.

3.3.3. Nitrous oxide ($N_2O$) emissions

Nitrous oxide ($N_2O$) is one of six greenhouse gases (GHG) targeted under the United Nations Framework Convention on Climate Change (UNFCCC). Addressing nitrous oxide ($N_2O$) would help deliver both climate and ozone benefits (Kanter et al. 2020). EDGAR emissions data for $N_2O$have been updated to 2018.

$N_2O$ emissions overall increased by 39% from 2000 to 2018 in Bangladesh.[10] For Bangladesh, and in line with results for South Asia as a whole, the largest contributor (92%) to $N_2O$ emissions in 2018 is 'other sectors' (see Figures 23 and 24). A further breakdown of the 'other sector' category reveals the main source of $N_2O$ emissions is from 'direct $N_2O$ Emissions from managed soils' at 59 Gg in 2018.[11] Managed soils are all soils on land, including forest land which is under management. 'Direct $N_2O$ Emissions from managed soils' is the main contributor of $N_2O$ for the rest of South Asia too. 'Other sectors' also covers 'indirect $N_2O$ emissions from managed soils', this was the second biggest contributor at 14 Gg in 2018 (Crippa et al. 2019b).

When the categories are aggregated, as in Figure 23, the biggest contributor of nitrous oxide ($N_2O$) emissions after 'other sectors' is the buildings sector (7%). Sector contributions from transport and power industry and other industrial combustion were minimal (<1%).

[10] Note that EDGAR data on $N_2O$ data is available for 2018.

[11] Hergoualc'h et al. (2019) describe the IPCC 2006 methodology estimates for $N_2O$ emissions "using human-induced net N additions to soils (e.g., synthetic or organic fertilisers, deposited manure, crop residues, sewage sludge), or of mineralisation of N in soil organic matter following drainage/management of organic soils, or cultivation/land-use change on mineral soils (e.g., Forest Land/Grassland/Settlements converted to Cropland)."

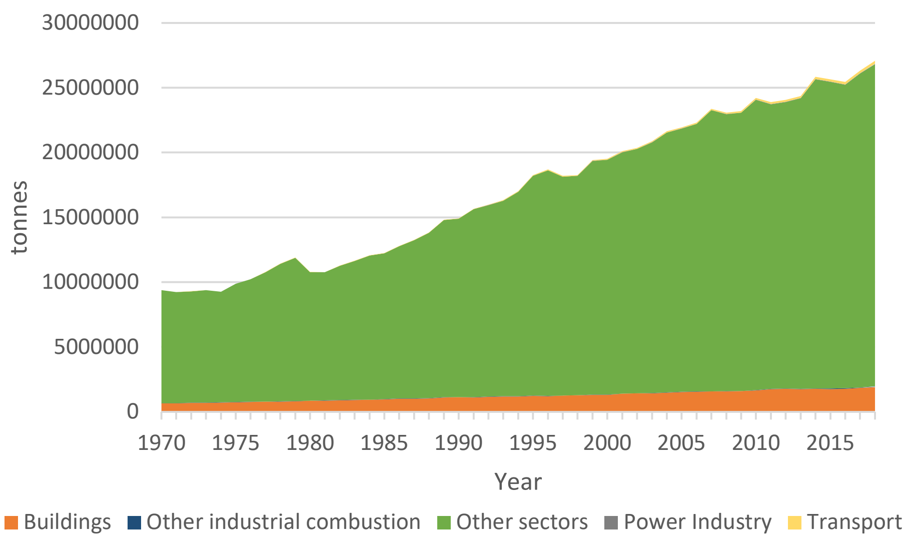



**Figure 23: Trend in the Nitrous oxide ($N_2O$) emission by sectors 1970-2015 in Bangladesh**

Source: EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b).

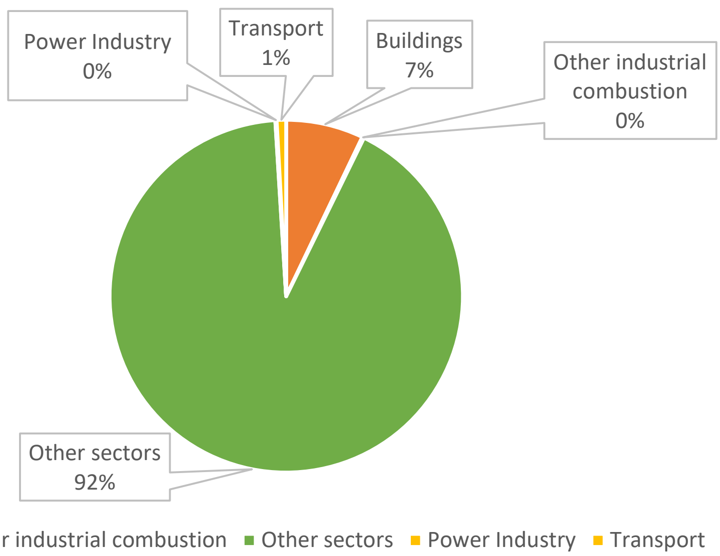



**Figure 24: Percentage of nitrous oxides ($N_2O$) emissions by sector for Bangladesh in 2015**

Source: EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b).

Table 13 illustrates the sub sector break down of the total $N_2O$ emissions in 2000 and 2108 and also the percentage change between those years, according to EDGAR data. The subsectors also includes the source of emissions in terms of fossil fuels (fossil) or biomass (bio). The largest sub-sector change for $N_2O$ emissions from 2000 to 2018 was for road transport with an increase of 575%. Yet overall contributions to emission in 2018 from this sub-sector were negligible. Sub-sectors that have also increased by 100% or more include 'indirect $N_2O$ emissions from the atmospheric deposition of nitrogen in $NO_x$ and $NH_3$', electricity and heat production, railways and water borne transport, Manufacturing Industries and Construction (fossil), and solid fuels (bio). All sectors identified as contributing the most to $N_2O$ emissions, were indicated to increase with the exception of

‘Manufacturing Industries and Construction’ (bio) (had a decrease of -100%) but again with negligible amounts.

According to rates of increase and overall contributions agriculture sub-sectors ‘Direct $N_2O$ Emissions from managed soils’, ‘Indirect $N_2O$ Emissions from managed soils’, ‘Wastewater Treatment and Discharge’ and ‘Indirect $N_2O$ emissions from the atmospheric deposition of nitrogen in $NO_x$ and $NH_3$’ and ‘other sectors (under buildings)’ are of most concern.

**Table 13: Nitrous oxides ($N_2O$) emission for different sectors between 2000 and 2018, in total (Gg per year) and percent change**

| Main sector category | IPCC code 2006 | IPCC 2006 sub sector description | Fossil or bio | Gg in 2000 | Gg in 2018 | % change 2000-2018 |
|---|---|---|---|---|---|---|
| Power industry | 1.A.1.a | Main Activity Electricity and Heat Production | Fossil | 0.02 | 0.11 | 450 |
| | 1.A.1.bc | Petroleum Refining - Manufacture of Solid Fuels and Other Energy Industries | Fossil | 0.00 | 0.00 | - |
| Transport | 1.A.3.b_no RES | Road Transportation no resuspension | Fossil | 0.04 | 0.27 | 575 |
| | 1.A.3.c | Railways | Fossil | 0.13 | 0.48 | 269 |
| | 1.A.3.d | Water-borne Navigation | Fossil | 0.01 | 0.05 | 400 |
| | 1.A.3.e | Other Transportation | Fossil | NULL | 0.00 | - |
| Buildings | 1.A.4 | Other Sectors | Fossil | 0.54 | 1.55 | 187 |
| | 1.A.4 | Other Sectors | Bio | 3.88 | 4.89 | 26 |
| | 1.A.5 | Non-Specified | Fossil | NULL | 0.00 | - |
| Other sectors | 3.A.2 | Manure Management | Fossil | 0.42 | 0.57 | 36 |
| | 3.C.1 | Emissions from biomass burning | Bio | 0.39 | 0.52 | 33 |
| | 3.C.4 | Direct $N_2O$ Emissions from managed soils | Fossil | 44.17 | 58.45 | 32 |
| | 3.C.5 | Indirect $N_2O$ Emissions from managed soils | Fossil | 10.02 | 13.50 | 35 |
| | 3.C.6 | Indirect $N_2O$ Emissions from manure management | Fossil | 0.31 | 0.47 | 52 |
| | 4.D | Wastewater Treatment and Discharge | Fossil | 4.07 | 6.25 | 54 |
| | 5.A | Indirect $N_2O$ emissions from the atmospheric deposition of nitrogen in $NO_x$ and $NH_3$ | Fossil | 1.35 | 3.55 | 163 |
| Other industrial combustion | 1.B.1 | Solid Fuels | Bio | 0.01 | 0.02 | 100 |
| | 1.B.2 | Oil and Natural Gas | Fossil | 0.00 | 0.00 | - |
| | 2.G | Other Product Manufacture and Use | Fossil | 0.04 | 0.05 | 25 |
| | 1.A.2 | Manufacturing Industries and Construction | Bio | 0.01 | 0.00 | -100 |
| | 1.A.2 | Manufacturing Industries and Construction | Fossil | 0.03 | 0.15 | 400 |
| | | Total $N_2O$ | | 65.46 | 90.87 | 39 |

Note: the total $N_2O$ emissions and percentage change in this calculation differ from Table 10 due to the differences in reference years. In this table the change is analysed between 2000 and 2018 and in Table 10 it’s between 2000 and 2015. EDGAR $N_2O$ emission data, at the time of writing, is the only dataset available up to 2018.
Source: EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b).

## 3.4. Summary of national Reactive Nitrogen Emission results

- The results on $N_r$ emissions for Bangladesh indicate that all three $N_r$ compounds of concern are on the rise and follow similar patterns to those identified for South Asia (SACEP & SANH 2022).
- These results highlight that current policy efforts so far have not been able to mitigate or reduce $N_r$ emissions. $N_r$ emission levels will continue to increase unless further policy action is taken at international, national and local levels.
- Nitrogen oxides ($NO_x$) in Bangladesh are the fastest rising $N_r$ compound and at the highest level particularly since the year 2000.
- For ammonia ($NH_3$) and nitrous oxides ($N_2O$), the emission levels in Bangladesh have been increasing steadily, and at a somewhat similar pace since the 1970s.
- The findings further reveal differences between the main sector sources for the different $N_r$ compounds. For example, agriculture is a major contributor to ammonia ($NH_3$) and directly managed soils for nitrous oxides ($N_2O$). For nitrogen oxides ($NO_x$) the main contributor is the power industry from electricity and heat production.
- Agriculture is a common emission source for all three $N_r$ compounds ($NO_x$, $NH_3$ and $N_2O$).
- The changes in $N_r$ emissions need to be considered in regard to the total contributions to identify where action is needed on emerging sectors.
- The recent changes in $N_r$ emissions also indicate where there have been increases and decreases between certain sector sources. These results highlight double threats, for example from $NO_x$ where the main sector source 'electricity and heat production' is the biggest contributor and with the largest increases in emissions (591%) between 2000 and 2015.
- The results indicate that different sectors contribute to the three $N_r$ compounds in various ways. The overlap in contributing sectors to different compounds indicate areas where integrated policies are necessary to avoid pollution swapping and promote coordinated actions to mitigate excess $N_r$ waste.

**Ammonia ($NH_3$):**

- For ammonia ($NH_3$), an ambient air pollutant, agriculture is by far the main pollution source (85% of total emissions in 2015) and emissions from this sector have been steadily increasing (by 32% from 2000 and 2015). Measures for sustainable $N_r$ management are urgently required here.
- Under agriculture 'Manure Management, Emissions from biomass burning, Urea application, Direct $N_2O$ Emissions from managed soils' were identified as major contributors to overall emissions and had all risen since 2000 to 2015.
- The buildings sector is also an area of concern, as the next major contributor to overall ammonia ($NH_3$) emissions (at 13%), with increases (of 23%) since 2000 and 2015.
- Other sectors (such as road transport, and power industry) experienced higher increases from 2000 and 2015 but overall contributions to $NH_3$ emissions were minimal (<0%), therefore these sectors do not yet present as priority areas for addressing $NH_3$.[12]

[12] 'Road Transportation' experienced a 4,500% increase from 2000 to 2015.

**Nitrogen oxides ($NO_x$):**

- For nitrogen oxides ($NO_X$) as an ambient air pollutant, there is a wider range of sectors (power industry, transport, other industry, agriculture and buildings), which due to overall emission contributions and increases in recent years require policy action.[13]
- For $NO_x$, the area of main concern includes the 'power industry' with emissions from electricity and heat production contributing 43% to overall emissions in 2015. Furthermore, this sector has experienced an extreme increase (591%) between 2000 and 2015.
- Transport and other industry (which includes Manufacturing Industries and Construction) are also major contributors (25 % and 15% respectively) to $NO_x$ emissions and experienced significant increases in the period between 2000 and 2015 ranging from 212- 343%. Therefore, these sectors should also be prioritised for $N_r$ management.
- For $NO_x$ the sectors 'agriculture' and 'buildings' also underwent increases in the same time period but by relatively smaller amounts (32-46%) yet these sectors still contribute to overall $NO_x$ emissions (7-10% to overall emissions), and therefore should be considered in policy actions to tackle $NO_x$ emissions.

**Nitrous oxide ($N_2O$):**

- The majority of $N_2O$ emission come from 'other sectors' which for this compound refers to the land use/agriculture sector. 'Direct and indirect $N_2O$ Emissions from managed soils' is the largest source and emissions have been increasing. This sector is identified as a priority policy area for tackling $N_2O$ emissions. Likewise, 'waste-water treatment and discharge' and 'Indirect $N_2O$ emissions from the atmospheric deposition of nitrogen in $NO_x$ and $NH_3$' have contributed to rising $N_2O$ emissions and are areas where $N_r$ reduction is needed.
- The building sector was the next major contributor to $N_2O$ emissions (6%), although with a lower increase (25%) between 2000 and 2018.
- The transport sector should be monitored as this had a sharper increase (63%) but overall contributions to emissions were minor in 2018 (1% mostly from road transport and railways) when compared to other sectors.
- A number of sub sectors had high increases, e.g., 100% or more, between 2000 and 2018, such as energy and electricity sector, but the overall contributions to $N_2O$ emission are negligible.

[13] Nitrogen oxides includes ($NO_2$) and nitric oxide (NO).

# 4. Policy Analysis

## 4.1. Brief methods overview

As part of the actions towards building 'the nitrogen policy arena for South Asia', nitrogen-related policies from South Asia were collected and analysed by SANH. Assessing nitrogen-related policies helps to identify the gaps and opportunities for managing nitrogen in Bangladesh and in the region. An analysis of this kind provides an initial starting point to understanding what policies are in place to help determine what is needed for the future to effectively and efficiently manage $N_r$. This policy assessment identifies what sectors and environmental sinks are focused on and which policy instruments are suggested and/or in place amongst other indicators for performance.

This work builds on from an initial global nitrogen policy assessment conducted by Kanter et al. (2020). Their global database had a collection of 2,726 policies from across 186 countries derived from the ECOLEX database. We adjusted the data collection approach and used multiple online data sources. We added to the 61 policies from South Asia identified by Kanter et al. from ECOLEX (2020) and created a new SANH policy database with a total of 966 polices for South Asia. The policies were collected during 2020-2021. See Table 14 for the overview nitrogen-relevant policies collected per country. Bangladesh nitrogen-related policies contribute 19% to the overall policies collected for South Asia.

**Table 14: Total Number of policies and percentage per country in the SANH database, breakdown by policy data source, and relevance and impact scope**

| Countries | SANH database 2019 total No. of policies | % of total SANH database | SANH database 2019 sources | | SANH subset policies high-medium relevance & large-medium scope |
|---|---|---|---|---|---|
| | | | Policies sourced from FAOLEX | Policies sourced from national websites | |
| Afghanistan | 89 | 9 | 79 (8%) | 10 (1%) | 58 (6%) |
| Bangladesh | 187 | 19 | 67 (7%) | 120 (12%) | 119 (12%) |
| Bhutan | 60 | 6 | 31 (3%) | 29 (3%) | 38 (4%) |
| India | 192 | 20 | 69 (7%) | 123 (13%) | 136 (14%) |
| Maldives | 40 | 4 | 20 (2%) | 20 (2%) | 29 (3%) |
| Nepal | 108 | 11 | 63 (7%) | 45 (5%) | 65 (7%) |
| Pakistan | 175 | 18 | 136 (14%) | 39 (4%) | 98 (10%) |
| Sri Lanka | 115 | 12 | 61 (6%) | 54 (6%) | 106 (11%) |
| South Asia | 966 | 100 | 526 (55%) | 440 (46%) | 649 (67%) |

Source: SANH Database (Yang et al. 2021).

The policy documents collected include legislation, acts, laws, ordinances, plans, strategies, regulations, statute, standards, rules, orders, codes, frameworks, and guidelines. To ensure coverage of all nitrogen-related policy documents, relevant sectors and sub-sectors were identified: agriculture, land use, environment, human health, marine, urban development, water and waste management, transport, energy, and industry. Within each country the responsible ministries and commissions for these sectors were also identified to assist the policy searches. For instance, not only ministries such as Chemicals and Fertilizers but also the less obvious ministries such as Health. The policies were then filtered, classified, and analysed. Figure 25 provides an overview of the methods.

*1.COLLECTION*

- Nitrogen-relavant policies were collected from multiple online web sources, including FAOLEX (a global database for environmental policy) and other sources including government and ministry websites. For the South Asia region, 55% of policies were sourced from FAOLEX and 45% from other web sources.

*2. FILTERING*

- Policies were filtered to ensure their relevance. This was done by identifying their relation to relevant sectors and sub-sectors. In addition, key words were used to guide assessments of relevance, such as the inclusion of certain key words like fertilizer, manure, N, N pollution, and nutrient pollution.
- Policies were further filtered by clustering. For instance, policies were checked to see if the policy was, or had, a 'central node' (core or original policy, such as an Act, Law or strategy) or whether it was, or had, subordinate policies (e.g., rules or regulations and/or a subnational policy), or an amendment (e.g., update to an existing policy). If it was an amendment it was assesed by whether there was substantial new content related to nitrogen compared to other related policies, and if so, it was kept as a separate entry. If the policy had been repealed, replaced or was only a minor amendment it was clustered. In other words it was not counted as an individual policy and it was clustered to the 'core' policy.

*3. CLASSIFICATION*

- Policies were classified based on their content. The classification was based on environmental sink, sector and sub sector, and policy type. The policies were further assessed based on their relevance to nitrogen, the impact scope, impact direction, and pollution source target.

*4. ANALYSIS*

- The polices were then analysed to identify patterns at the regional and national levels and to identify trends over time.

**Figure 25: An overview of the nitrogen policy assessment methods adopted by SANH**

## 4.2. Policy Classification

The nitrogen-related policies collected were classified based on certain characteristics to identify patterns in the types of polices in place for each country. Policies were classified by environmental sink, sector, sub-sector, policy type, pollution source type, impact direction, relevance, and impact scope. The classifications list is provided in Table 15. The classification approach followed closely the global study approach used by Kanter et al. (2020), with additional classifications. For classification definitions see Appendix Table 3.

**Table 15: SANH nitrogen–relevant policy classification lists**

<table>
<tr><th>Categories</th><th colspan="2">Classification</th></tr>
<tr><td>Sink</td><td colspan="2">Air; water; soil; climate; ecosystem; multiple; no sink included</td></tr>
<tr><td rowspan="11">Sector</td><td>Agriculture</td><td>Synthetic fertilizer<br>Manure management<br>Crop residues<br>Organic farming Livestock<br>Aquaculture<br>Agriculture other</td></tr>
<tr><td>Waste</td><td>Municipal waste<br>Industrial/ commercial waste<br>Flood water<br>Medical waste<br>Organic waste</td></tr>
<tr><td>Food</td><td>Food safety<br>Food security Food waste</td></tr>
<tr><td>Energy</td><td>Low carbon and renewable<br>Non-renewable energy Biofuel and bioenergy</td></tr>
<tr><td>Transport</td><td>Road transport<br>Aviation<br>Rail Maritime & inland water transport<br>Transport other<br>Biomass burning</td></tr>
<tr><td>Land use change</td><td>Forestry<br>Other land use and land use change</td></tr>
<tr><td colspan="2">Industry</td></tr>
<tr><td colspan="2">Urban dev. & tourism</td></tr>
<tr><td colspan="2">Other</td></tr>
<tr><td colspan="2">Multiple</td></tr>
<tr><td colspan="2">No sector included</td></tr>
<tr><td>Policy type</td><td colspan="2">Regulatory; economic; framework; data & methods; research & development (R&D); commerce; pro-nitrogen</td></tr>
<tr><td>Pollution source type</td><td colspan="2">Point source; non-point source; both; unspecified; non-applicable</td></tr>
<tr><td>Impact direction</td><td colspan="2">Positive; negative; mixed / neutral</td></tr>
<tr><td>Impact scope</td><td colspan="2">Large; medium; small</td></tr>
<tr><td>Relevance</td><td colspan="2">High; medium; low</td></tr>
</table>

## 4.3. Nitrogen-related policy status for Bangladesh – SANH dataset

### 4.3.1. Relevance and scope

Table 16 shows the number and percentage of policies according to their relevance and impact scope. This classification can be helpful in managing nitrogen and/or policy improvement by tracking those policies that are highly relevant as well as with the potential to have a larger impact on $N_r$ management. Policies were defined as direct and with high relevance, by whether they featured one or more of the 29 key words in the policy text.[14]

[14] The 29 key words were: fertilizer, manure, Nitrogen (N), Nitrogen pollution, nutrient pollution, nitrate, nitrates, ammonia, N oxides, nitrous oxide, $N_2O$, $NH_3$, $NO_3$, $NO_x$, eutrophication, hypoxia, air quality, air pollution,

**Table 16: Number of nitrogen-related policies in Bangladesh for relevance and impact scope, 2019**

| Relevance | Impact scope | | | Total |
|---|---|---|---|---|
| | Large | Medium | Small | |
| High (direct) | 45 (24%) | 42 (22%) | 9 (5%) | 96 (51%) |
| Medium (indirect) | 6 (3%) | 26 (14%) | 2 (1%) | 34 (18%) |
| Low (indirect) | 0 | 22 (12%) | 35 (19%) | 57 (30%) |
| Total | 51 (27%) | 90 (48%) | 46 (25%) | 187 (100%) |

Source: SANH Database (Yang et al. 2021).

Among the selected 187 policies, 51% (96) policies were classified having direct and high relevance for Bangladesh. Since the policies contains at least one of the 29 key words, they were found to have direct and high relevance to $N_r$. For example, 'Fertilizer Management Act 2006 *Amendment 2018' focuses on synthetic fertilizers (e.g., balanced use, and maintaining quality). By contrast, 'National Agriculture Policy, 2018' emphasises sustainable agricultural growth and with the continuation of subsidies on fertilizer and other agricultural inputs, focus has been given towards balancing out the support provided for urea and non-urea fertilizers.

Indirectly relevant policies with 'medium' relevance do not contain one of the 29 key words but may feature synonyms of those words. A total of 34 policies (18%) were classified with indirect and medium relevance for Bangladesh e.g., 'Bangladesh Industrial Design Act, 2016 (draft)', 'National Co-operative Policy' etc.

Policies associated with certain sector(s) or sink(s) were presumed to have indirect links and low relevance to $N_r$ management. 30% of Bangladesh policies were classified with low relevance e.g., 'Plant quarantine Act', 'Fish and Animal Feed Act 2010' and 'National Salt Policy 2016'. Despite having indirect relevance to $N_r$, these policies might still have implications on $N_r$ management. For example, 'Fish and Animal Feed Act 2010' can impact $N_r$ pollution through discharge and waste management.

Table 16 also depicts the number and percentage of policies according to their impact scope. Impact scope indicates towards a policy's spatial coverage and its pertinence for $N_r$ management. For example, policies having large impact scope mostly includes national level policies, which have the potential to influence a large number of people and are more directly relevant to $N_r$ management. In Bangladesh, 51 policies (27%) were classified with large impact scope e.g., 'Organic Agriculture Policy', 'Bangladesh Biodiversity Rules 2012', and 'National Environmental Policy'.

48% of policies (90) were classified with medium impact scope, which includes sub-national policies, or those less directly relevant to nitrogen, e.g., ''Cage fish farming policy in Jal mahal (flowing rivers and other water bodies), 2019''.

Policies focusing on a very specific location or zone or nationwide but with distant consequences for $N_r$ management were classified with small impact scope. A total of 46 policies (25%) in Bangladesh fell under this classification, e.g., ''CHT Land Acquisition Regulation 1958'' and ''Marine Fisheries Sector Sub-strategy, 2006''.

4.3.2. Policy types

Policy type, as a classification category, indicates what type of policy instruments are being suggested or applied within a particular policy. A single policy may have multiple policy type characteristics e.g.,

emissions, groundwater quality, groundwater pollution, freshwater quality, freshwater pollution, water quality, ozone depletion, climate change, greenhouse gas, agrochemical and effluent.

framework, data and methods and research and development (R&D). Policies with multiple instruments are preferred because they are considered to be more comprehensive. For Bangladesh there were 279 classifications from the 187 policies (Table 17). 74 policies (39%) had more than one policy type identified.

**Table 17: Number and percentage of nitrogen-related policies in Bangladesh for policy type**

| Policy Type | Total No. of classifications | % of classification |
|---|---|---|
| Regulatory | 12 | 4 |
| Economic | 2 | 1 |
| Framework | 171 | 61 |
| Data & methods | 21 | 8 |
| Research & development (R&D) | 63 | 23 |
| Commerce | 9 | 3 |
| Pro-N | 1 | 0 |
| Total | 279 | 100 |

Note: the total number is 279 as this is the total number of classifications, as each policy could be classified as having multiple policy types.
Source: SANH Database (Yang et al. 2021).

The most common classification for policy type is framework (61%) which includes policies with broad objectives and/or designate governing bodies, e.g., 'National Integrated Pest Management Policy, 2002.' Research and development (R&D) is the second most common classification (23%) followed by Data and methods (8%). Regulatory (4%) and Economic (1%) policies are considered 'core nitrogen policies' as outlined by Kanter et al. (2020) since they directly address nitrogen production, consumption or loss in a measurable way. Regulatory policies would also feature as a standard and set guidelines that are set in law and may also feature data and methods policy characteristics in order to monitor compliance.

Pro-nitrogen policy featured as the least common types having only one policy, namely 'Non-Urea Fertilizer Import, Sell and Subsidy Disbursement Procedure' aiming to provide financial and institutional support in fertilizer disbursement, while ignoring any environmental concern.

#### 4.3.3. Sectors and sub-sectors

Table 18 illustrates the total number of Bangladesh's nitrogen relevant policies and their percentages broken down by sector and sub-sector type. Primary sectors were found to be divided among several subsectors and consequently percentage of policies was quite dispersed among sub-sectors. The agricultural sector was found to be the most common classification (35%). Some policy examples are 'National Agricultural Extension Policy, 2015 (draft)' and 'National Agriculture Policy, 2018'. The second most common classification was for multiple sectors (13%), which is considered a beneficial policy characteristic indicating the role of multiple sectors in $N_r$ management.

**Table 18: Number and percentage of nitrogen-related policies in Bangladesh for sectors and sub-sectors**

| Main Sector | No. of policies | % of policies | Sub-sector | No. of policies | % of policies |
|---|---|---|---|---|---|
| Agriculture | 65 | 35 | Agriculture other | 8 | 4 |
| | | | Livestock | 10 | 5 |
| | | | Aquaculture | 19 | 10 |
| | | | Organic Farming | 1 | 1 |
| | | | Synthetic Fertilizer | 5 | 3 |
| | | | Multiple | 2 | 1 |
| | | | Non-applicable | 20 | 11 |
| Waste and Water | 4 | 2 | Medical Waste | 1 | 1 |
| | | | Industrial and Commercial waste | 2 | 1 |
| | | | Non-applicable | 1 | 1 |
| Industry | 7 | 4 | Multiple | 1 | 1 |
| | | | Non-applicable | 6 | 3 |
| Food | 14 | 7 | Food Security | 5 | 3 |
| | | | Food Safety | 5 | 3 |
| | | | Multiple | 3 | 2 |
| | | | Non-applicable | 1 | 1 |
| Energy | 16 | 9 | Low carbon and renewable | 1 | 1 |
| | | | Non-renewable energy | 1 | 1 |
| | | | Biofuel and bioenergy | 1 | 1 |
| | | | Non-applicable | 13 | 7 |
| Transport | 17 | 9 | Road transport | 7 | 4 |
| | | | Rail | 1 | 1 |
| | | | Aviation | 1 | 1 |
| | | | Maritime and inland water transport | 6 | 3 |
| | | | Transport other | 1 | 1 |
| | | | Non-applicable | 1 | 1 |
| Land Use Change and Forestry | 14 | 7 | Forestry | 7 | 4 |
| | | | Other land use and land use change | 2 | 1 |
| | | | Multiple | 2 | 1 |
| | | | Non-applicable | 3 | 2 |
| No sector included | 19 | 10 | Non-applicable | 19 | 10 |
| Multiple | 25 | 13 | Non-applicable | 25 | 13 |
| Other | 6 | 3 | Non-applicable | 6 | 3 |
| Total | 187 | 100 | | 187 | 100 |

Note: For urban development and tourism, no sub-sectors were identified. For any main sector policy classified as 'Multiple' and 'Other' for sub-sectors they were by default classified as non-applicable. Non-applicable represents a general sector policy that does not specify a sub-sector.

Source: SANH Database (Yang et al. 2021).

Around 10% of policies did not include a reference to any sector, e.g., the policies might focus only on one or more environmental sinks. For example, "National Water Policy" and 'Bangladesh Climate Change strategy and Action Plan, 2009'. While such policies should ideally be linked to sector actions, sink oriented policies are still considered positive (above sector-only oriented policies) because they focus on environmental protection and sustainability actions. Classification for other main sectors formed a small percentage (ranging from 2% to 9%).

The category for sub-sectors (see Appendix Table 3 for the full classification list) identifies policies with a more specific sector focus. Non-applicable was the most common classification under this category as it is a default for policies that specify only a main sector, with no sub-sectors listed, or for policies that are generalised and do not refer to any specific area. The next most common classification was for aquaculture (10%), followed by livestock (5%) and then agriculture other, forestry and road transport (4%). Some examples from these subsectors include, 'Code of Conduct for Various Segments of the Aquaculture-Based Shrimp Industry in Bangladesh', 'National Poultry Development Policy, 2008' and 'National Crop and Forest Biotechnology Policy-2012'. The rest of the sub-sectors were small in number with ≤3% of policies.

#### 4.3.4. Environmental sink

The classification for environmental sinks indicates if a policy is oriented in its objectives or intent towards climate, water, air, soil, and/or ecosystems (Appendix Table 3). As a category, sinks can also reflect the environmental aspect at risk (under threat) from $N_r$. A policy may refer to more than one sink, and if so, would be classified as multiple.

For Bangladesh, most of the policies were classified under the category 'no sink' (73%). This means that more than 70% of the total collected policies were completely sector oriented. Such policies have limitations, as these policies did not consider the potential risk or the option to mitigate $N_r$ impact on the environment. Examples include policies such as 'National Integrated Pest Management Policy', 'Bangladesh tourism protected areas and special tourism zone Rules, 2013' and 'Food grain & Food Product Movement policy, 2008'.

**Table 19: Number and percentage of nitrogen-related policies in Bangladesh for environmental sinks**

| Sink | No. of policies | % of policies |
|---|---|---|
| Water | 11 | 6 |
| Air | 1 | 1 |
| Ecosystem | 13 | 7 |
| Climate | 7 | 4 |
| Multiple sinks | 18 | 10 |
| No sink Included | 137 | 73 |
| Grand Total | 187 | 100 |

Source: SANH Database (Yang et al. 2021).

The next common classification was for multiple sinks (10%). This is considered to be a favourable feature for policies since it focuses on different aspect of the environment altogether. One such policy example is 'Bangladesh Delta Plan 2100' that addresses almost all the sinks at different points.

Among the single sink categories ecosystem was found to be the most common with 7% of total policies, followed by water at 6%. While the lowest percentage (only 1%) focused sink 'air' with the sink 'climate' held slightly higher percentage (4%). Given the alarming and increasing air pollution concern regarding air pollution and though air may be covered by policies referring to multiple sinks, more focus and attention for the sink ‘air’ at the policy level should be given topmost priority.

The Bangladesh government has taken various measures to mitigate environmental pollution, especially air pollution. The Climate and Clean Air Coalition (CCAC) was formed under UN sponsorship in 2012, focusing on the reduction of Short-Lived Climate Pollutants (SLCPs) through targeting major source sectors. Bangladesh, as one of the founding partners of CCAC, aims to sustainably increase the level of actions taken to reduce SLCPs at the national level. The National Action Plan primarily targets black carbon and methane emissions, but one key policy Nationally Determined Contributions (NDCs) referred to the control of GHG and PM emissions, thus including the reduction of $N_r$ as a target. The NDC implementation roadmap and action plan update from 2018 enhances the ambition of NDCs by incorporating Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and other Land use (AFOLU) and Waste together to tackle the growing emissions. The Agriculture, Forestry and other Land use (AFOLU) sector under NDCs targets mitigating $N_2O$ emission from nitrogen-based fertilizers along with methane from livestock farming and rice field emissions (DOE 2018b; MoEFC 2021). Such action plans are promising to control air pollution, although inclusion of more pollutants e.g., $N_r$ substances and PM can ensure more comprehensive coverage. The actions for cleaner air and for the NDC to combat climate change are both promising actions and policies, that needn’t be distinct from each other.

### 4.3.5. Pollution source

Policies that are directly relevant to $N_r$ and concerned with environmental protection should aim to target and mitigate against $N_r$ pollution effectively by recognising the difference between pollution type sources. Point source and non-point source (NPS) pollution involve different challenges and different mitigation measures needed to address them.

Nitrogen pollution released as a ‘point source’ refers to whether it is discharged directly into water or into the atmosphere at a ‘discrete point’, making it easier to control and monitor. Around 11% of the listed policies were identified as ‘point source’ (Table 20), such as ‘Fertilizer (Management) (Amendment) Act, 2018’ which developed a coherent policy for fertilizer management in Bangladesh.

**Table 20: Number and percentage of nitrogen-related policies in Bangladesh by pollution type source**

| Pollution type source | No. of policies | % of policies |
|---|---|---|
| Point source | 20 | 11 |
| Non-point source (NPS) | 9 | 5 |
| Both pollution type sources | 26 | 14 |
| Unspecified | 32 | 17 |
| Non-applicable | 100 | 53 |
| Total | 187 | 100 |

Source: SANH Database (Yang et al. 2021).

NPS covers $N_r$ pollution that comes from various land, air and/or water sources and can be carried overland, underground, and/or in the atmosphere, making it difficult to measure and control (Islam et al. 2018; Liu et al 2020). Nine policies (5%) were classified as ‘non-point source’ in Bangladesh, which is the lowest percentage in this category.

The most common classification was for non-applicable category (53%), since it was default classification for policies classified with a negative impact direction, and/or as having an indirect relevance to nitrogen. For around 17% of policies the pollution source type was unspecified. This finding highlights a policy gap that can impose disadvantages on a policy's ability to support sustainable $N_r$ management by efficiently targeting the source of pollution. So, here arises an opportunity to amend the policies for better screening of pollution sources (i.e., at least one source) and subsequently more efficient $N_r$ management. Environmental policy in general recognizes either point source or NPS but it is beneficial to consider both, since considering both sources indicate a more widespread understanding how $N_r$ enters the system and can also help in undertaking relevant actions. For Bangladesh, 26 (14%) policies were categorized as considering both pollution type sources, e.g., 'Bangladesh Strategic Plan on Agricultural and Rural Statistics (2016-2030)' and 'Bangladesh Country Investment Plan for Environment, Forestry and Climate'.

#### 4.3.6. Impact direction

Impact direction was introduced by the SANH study as a classification to indicate whether a policy was presumed to have a positive, negative or mixed/neutral impact on $N_r$ pollution. It is worth highlighting that this is based on the assessment of the policy text. Evidence of actual policy impacts on $N_{r,}$ whilst outside the scope of this study so far, would be necessary to determine how those policies work in practice. All the policies require further scrutiny to determine effectiveness in linking proposed objectives to actual impacts.

Policies presumed to have the ability to have a positive impact were the most common (44%). Such policies were considered to encourage reduced nitrogen pollution and/or improved nitrogen management either directly or indirectly. Among the three categories, 19% were classified as having 'negative impact' where environmental consideration was absent from the policy text e.g., 'The Ship Breaking and Recycling Rules, 2011' and 'National Livestock Development Policy, 2007'. This is an undesirable policy characteristic as such policies have the potential to increase $N_r$ into the atmosphere. Although it is the lowest percentage among the three categories, policies classified as negative indicate a potential policy gap where greater focus on the environmental aspect e.g., $N_r$ management, would be an advantage.

**Table 21: Number and percentage of Bangladesh nitrogen-relevant policies for impact direction**

| Impact direction | No. of policies | % of policies |
|---|---|---|
| Positive | 82 | 44 |
| Negative | 36 | 19 |
| Mixed/neutral | 69 | 37 |
| Total | 187 | 100 |

Source: SANH Database (Yang et al. 2021).

The third classification for impact direction was 'mixed/neutral', which identified policies that may have both positive and negative impacts, e.g., a policy that aims to enhance food production and increase access to fertilizer but also considers the environmental impacts, or a policy that is potentially neutral in its impacts (i.e., neither positive nor negative). Around 37% of policies were classified as mixed/neutral, which can have uncertain implications with respect to sustainable $N_r$ management. Further assessments of the mixed/neutral policy group would be needed to identify how far these policies could achieve sustainable outcomes.

### 4.4. Stand out policies

Stand out policies in this assessment are identified as those that include references to multiple sinks and/or sectors and/or include multiple policy instruments, as being those potentially best placed to support sustainable $N_r$ management. Among all the identified nitrogen policies around 4% (a total of

8) meet these criteria and are classified as having highest relevance and impact scope towards nitrogen, as outlined in Table 22.

**Table 22: Bangladesh nitrogen-related policies that refer to multiple sinks, sectors with high relevance and classification for impact direction and pollution source**

| Policy name | Impact direction | Pollution Source Type |
|---|---|---|
| 1. Bangladesh Country Investment Plan for Environment, Forestry and Climate Change (EFCC CIP) 2016-2021. | POSITIVE | BOTH |
| 2. National Environmental Policy 2018 | POSITIVE | BOTH |
| 3. Environment Conservation Rules, 1997 | POSITIVE | BOTH |
| 4. Bangladesh National Programme of Action for Protection of the Coastal and Marine Environment from Land-Based Activities | POSITIVE | BOTH |
| 5. Bangladesh Delta Plan 2100 | POSITIVE | BOTH |
| 6. Coastal Zone Policy 2005 | POSITIVE | BOTH |
| 7. Master Plan for Haor Area | MIXED/NEUTRAL | BOTH |
| 8. Coastal Development Strategy 2006 | POSITIVE | POINT SOURCE |

Source: SANH Database (Yang et al. 2021).

Again, considering the pollution source types, with the exception of the 'Coastal Development Strategy 2006' all the remaining seven policies refer to both pollution source type (NPS and point source). These seven policies stand out further as having a greater potential to deal with the complicated nature of $N_r$ management. Moreover, all but one of these selected policies have positive impact direction, hence are directed towards addressing and mitigating environmental pollution from multiple perspectives (sink and/or sector).

## 4.5. Cross comparisons of classification for selected policies

For a better understanding of policies related to nitrogen management this section focuses on those having a more direct relevance to $N_r$. In this case policies were classified by filtering out those with low relevance and/or low impact scope (see Table 16). Around 36% of the policies were omitted and the remaining 67% (119 policies) were identified as of medium to high relevance and scope. The policies with high to medium relevance and scope have the potential for higher impact on how $N_r$ enters the environment. Policies with lower scope and relevance should not be completely discounted since they still pose the potential to influence to $N_r$ management, and could be amended to promote sustainable management.

Cross comparisons of all nitrogen related policies (sinks vs sector, policy type vs sink, policy type vs sector) are discussed in Appendix section two, while the following section illustrates the cross comparison of two classification types (relevance and impact direction). The following classifications are compared: sink and sector, pollution source and impact direction, and sector and sub-sectors with policy types.

### 4.5.1. Selected policies by sink and sector (integration)

Table 24 illustrates the selected policy classifications by environmental sink and main sectors. The result depicts a somewhat similar frame to the full dataset, with some differences. Single sector agricultural policies without referring to any sink remains the most common classification despite the reduction in percentage by 3% (28%). Single sector oriented industrial (4%) and food (8%) policies also feature as higher percentage by 1%, whereas land use change and forestry policies decreased by 3% from the full dataset (2% from 5%).

Among the sink-oriented policies without referring to any sector, water (7%) and ecosystem (3%) feature as a higher percentage by 3% and 1% respectively, e.g., 'Bangladesh Water Act, 2013' and 'Bangladesh Biodiversity Rules, 2012'.

The overall percentage of policies with multiple sectors referring to different environmental sinks feature a higher percentage (by 9%) in this classification than in the full dataset. Among the single sink-oriented policies referring to multiple sectors, Ecosystem (6%) and climate (2%) oriented policies have higher percentages by 3% and 1% respectively. Multiple sectors policies without any sink rise to 7% from 5% based on the full dataset result.

Selected policies referring to multiple sectors and environmental sinks (% of policies in this category has increased from 5% to 8% than in full dataset), are considered to be favourable due to their indication of integrated objectives. For example, 'National Environmental Policy 2018', 'Bangladesh Delta Plan 2100' etc. are such policies with high and/or medium relevance and scope, referring to multiple sectors and environmental sinks. Despite the rise in percentage, such policies are still very low in proportion indicating that 92% of policies still lack integration. The result warrants further attention for action in this policy area.

**Table 23: Percentages of selected nitrogen-relevant policies for sink and sector, Bangladesh**

| Sink | Sector | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | Waste and wastewater | Industry | Food | Energy | Transport | Land use change and forestry | Other | No sector included | Multiple | |
| Air | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Water | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 8 |
| Climate | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 2 | 5 |
| Ecosystem | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 6 | 9 |
| Multiple | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 8 | 13 |
| No sink included | 28 | 1 | 4 | 8 | 7 | 7 | 2 | 2 | 0 | 7 | 63 |
| Total | 33 | 2 | 5 | 8 | 8 | 7 | 2 | 3 | 13 | 22 | 100 |

Note: Selected policies are those with high–medium relevance and impact scope, a total of 119 policies.
Source: SANH Database (Yang et al. 2021).

### 4.5.2. Selected policies by source and impact direction (integration)

In this classification category among the 119 policies, around 51% (Table 25) policies were found to have positive impact direction which is 7% higher than the full dataset. The proportion of policies having negative (13%) and mixed/neutral (35%) impact direction have decreased in percentage by 6% and 2% respectively. The changes in proportion are somewhat desirable for better $N_r$ management, in this classification with high and/or medium relevance and impact scope. Positive impact direction policies (14%) were commonly associated with both kinds of sources (point and NPS) indicating desirable policy characteristics. 10% of policies in this classification were found to be associated with point source and 6% were with non-point source. Positive policies with unspecified sources constituted around 8% of policies (e.g., 'Non-Urea Fertilizer Import, Sell and Subsidy Disbursement

Procedure'). This finding suggests that there is scope for improvement through introducing environmental considerations as well as amendments to include pollution source type as relevant to the specific policy.

**Table 24: Percentage of selected Bangladesh nitrogen-relevant policies for pollution source and impact direction**

| Impact direction | Point | Non-point Source | Both | Unspecified | Non-applicable | Total |
|---|---|---|---|---|---|---|
| Positive | 10 | 6 | 14 | 8 | 13 | 51 |
| Negative | 0 | 1 | 0 | 0 | 13 | 14 |
| Mixed/Neutral | 6 | 1 | 8 | 12 | 9 | 35 |
| Total | 16 | 8 | 22 | 19 | 35 | 100 |

Note: Selected policies are based on high–medium relevance and impact scope, a total of 119 policies.
Source: SANH Database (Yang et al. 2021).

For mixed/neutral impact policies 12% of policies were classified with unspecified source of pollution, suggesting that further careful attention is needed to consider how to incorporate pollution sources. For negative impact direction policies most (13% out of the 14% of policies in this category) were classified as non-applicable by default. The percentage of non-applicable policies has reduced by 18% since policies with lower relevance and scope were dropped in this classification. Among the policies applicable to pollution source type, policies addressing both (point and NPS) sources were higher in proportion, which increased by 8% from the overall dataset.

### 4.5.3. Selected policies by sector, sub-sector and policy type

Table 26 compares policies in accordance with sector, sub-sector and policy type, while limiting the classification to policies with high and/or medium relevance and impact scope. The agricultural sector policies remained the most common (36%), similar to the finding from the full dataset (table 20). The second most common classification was for the policies referring to multiple sectors (20%) that increased by about 6% from the full dataset result.

The most common policy type, similar to the findings from the whole dataset, was framework (56%) and then R&D (24%), data and methods (9%), regulatory (6%) and commerce (5%). Prioritizing research and development while developing policies is a desirable policy characteristic. Still, it provides an opportunity to be more dispersed across different sectors rather than concentrating on agricultural policies or multi-sectoral policies.

Among the single sector policies, agricultural policies stand out as majority (36%) and also as broad framework policies (18%). Meanwhile, for subsectors, non-applicable was most commonly (17%) designated and then aquaculture (12%) was second. Framework was classified as the most common type in agriculture-focused policies despite a 1% decrease from the complete dataset. The second most common policy type was R&D (9%) remaining at the same proportion as full dataset. A similar sequence was also obtained in the case of multiple sector policies where framework holds the highest (11%) and then R&D (6%). Most combinations are ≤3%.

**Table 25: Percentage of selected Bangladesh nitrogen-relevant policies for sector, sub-sectors and policy type**

| Sectors and sub-sectors | Policy Type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Regulatory | Economic | Framework | Data and methods | R&D | Commerce | Pro-N | Total |
| **Agriculture** | 3 | 0 | 18 | 4 | 9 | 2 | 1 | **36** |
| Synthetic Fertilizer | 1 | 0 | 3 | 0 | 0 | 2 | 1 | 6 |
| Organic Farming | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| Livestock | 1 | 0 | 3 | 0 | 2 | 0 | 0 | 6 |
| Aquaculture | 1 | 0 | 5 | 3 | 3 | 0 | 0 | 12 |
| Agriculture Other | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 3 |
| NA | 0 | 0 | 5 | 1 | 2 | 0 | 0 | 7 |
| Multiple | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| **Waste & Wastewater** | 0 | 0 | 2 | 0 | 0 | 0 | 0 | **2** |
| Medical Waste | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Industrial/commercial waste | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| NA | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| **Industry** | 1 | 0 | 2 | 0 | 1 | 0 | 0 | **4** |
| NA | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 3 |
| Multiple | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| **Food*** | 1 | 1 | 4 | 1 | 1 | 1 | 0 | **6** |
| Food Safety | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 3 |
| Food Security | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 2 |
| Multiple | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 2 |
| **Energy** | 0 | 0 | 5 | 1 | 1 | 2 | 0 | **8** |
| Non-renewable energy | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 2 |
| Biofuel and bioenergy | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| NA | 0 | 0 | 4 | 0 | 1 | 1 | 0 | 5 |
| **Transport** | 1 | 0 | 4 | 0 | 1 | 1 | 0 | **6** |
| Road Transport | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Rail | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 2 |
| Aviation | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Maritime and inland water transport | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| NA | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| **Land Use Change and Forestry*** | 0 | 0 | 3 | 0 | 0 | 0 | 0 | **3** |
| Forestry | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| Other Land Use and Land Use Change | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Multiple | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| **Other*** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | **1** |
| **Multiple** | 2 | 0 | 11 | 1 | 6 | 0 | 0 | **20** |
| **NA** | 0 | 0 | 8 | 3 | 5 | 0 | 0 | **15** |
| **Total** | **6** | **1** | **56** | **9** | **24** | **5** | **1** | **100** |

Note: Rows with bold texts indicate the main sectors and the subtotal for sub-sectors. Selected policies include those with high–medium relevance and impact scope, a total of 119 policies. The percentages are based on the total number of classifications, a total of 196 for the selected policies.
Source: SANH Database (Yang et al. 2021).

# 5. Drivers of $N_r$ Emission and Policy Change

## 5.1. Bangladesh nitrogen related policies over time

To better understand $N_r$ pollution and its related policy approaches in Bangladesh, policies were filtered repeatedly to identify and include in the 2019 database only policies which were active. Bangladesh has policies of environmental relevance since the 1970s with the 'East Pakistan Water Pollution Control Ordinance (No. V of 1970)' and 'Bangladesh Environment Conservation Act, 1995. (Act No. 1) *amended by Act No.12 of 2000 and 9 of 2002, and 2010).' Although these are environment focused policies, some of them were formulated a long time ago and might require revision/updates for better $N_r$ management using more up-to-date understandings of the issues. These policies were more sink specific (wildlife conservation, carbon pollution etc. were of more concern), and did not specify the sectoral impact of nitrogen emissions on environment sufficiently. Since economic growth was the primary focus then, sector specific policies lacked environmental considerations.

There are significant differences in the number of policies from different sectors through time i.e., Pre-2000, 2001-2010, and 2011-2019. With increasing population, rapid growth and industrialization, the environment of Bangladesh has been severely damaged. Consequently, environmental concerns have taken their place in policy development. While only 21% of nitrogen related policies were developed before 2000, going up to 24% during 2001-2010, 55% (31% rise from the previous years) of nitrogen related policies were formulated during 2011-2019. This indicates an increment of sector-specific policies over time for every sector. The most common policies are agricultural sector policies and these have increased by 10% from 2001-2010 to 2011-2019. The finding is not surprising, as Bangladesh is an agrarian country. With ever-growing population and industrial growth not only farming, but also other sectors (e.g., energy, food, industry), must be modernized while accounting for better environmental management (e.g., how $N_r$ enters the activities and how to mitigate $N_r$ pollution). Hence with time $N_r$ relevant policies are also increasing to attempt sustainable management of the environment.

Figure 26 shows the nitrogen related policies in Bangladesh, broken down by sectors for pre-2000, 2001-2010 and 2011-2019. Policies referring to a single sector (e.g., agriculture) increased substantially during the 2011-2019 period. On the contrary, sink-oriented policies were found stagnant except for multiple sink-oriented policies and there was a sharp increase in the number of policies that did not refer to any environmental sink during 2011-2019 (Figure 26).

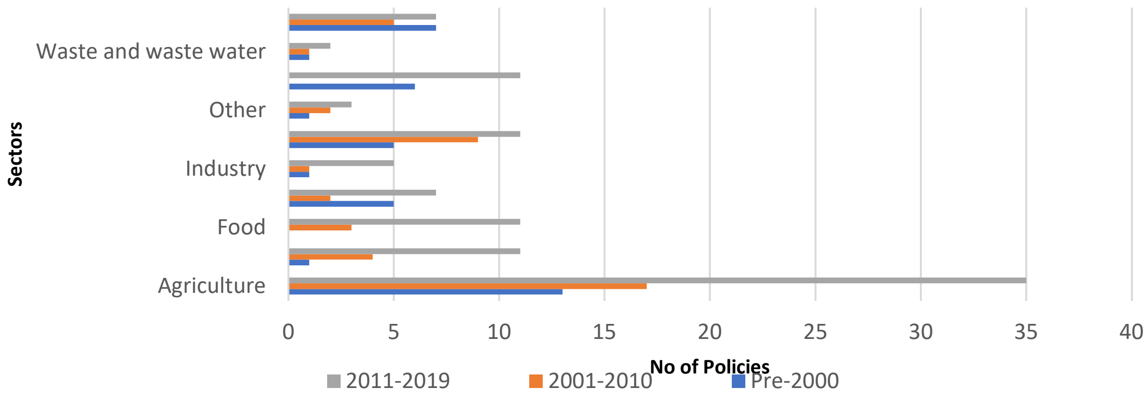



**Figure 26: Bangladesh nitrogen-related policies broken down by sector for Pre-2000, 2001-2010 and 2011- 2019**

Source: SANH Database (Yang et al. 2021).

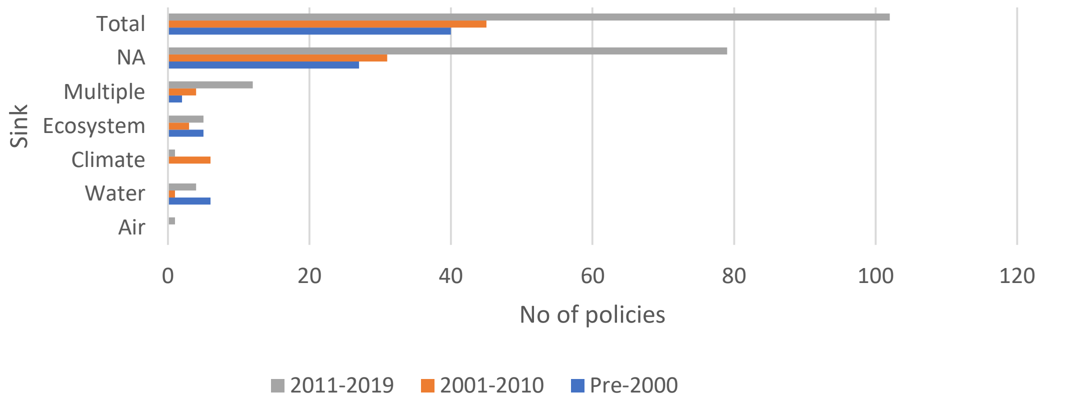



**Figure 27: Bangladesh nitrogen-related policies broken down by sink for Pre-2000, 2001-2010 and 2011- 2019**

Source: SANH Database (Yang et al. 2021).

Figure 27 illustrates Bangladesh nitrogen related policies over time, broken down by policy types. Framework policies were higher in number during every time frame, followed by R&D. There was a substantial increment in number for these policy types during 2011-2019, relative to other policy-type classifications.

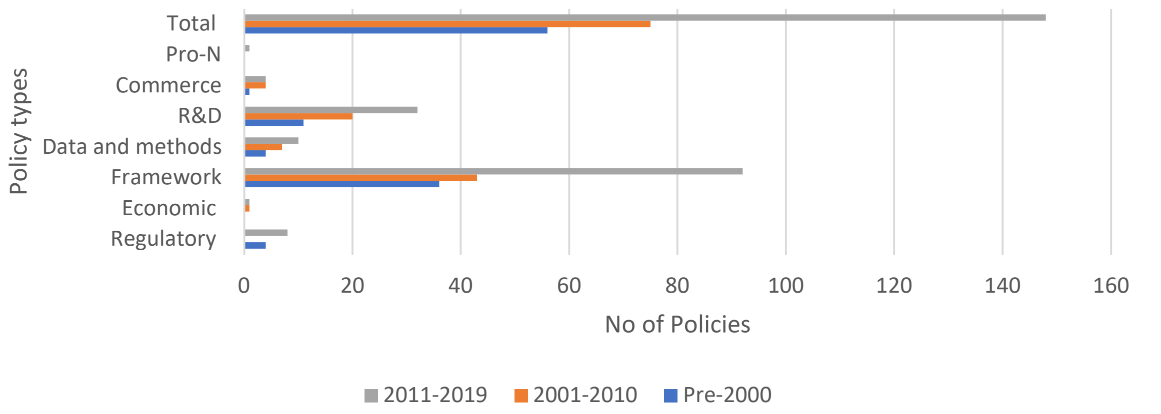



**Figure 28: Bangladesh nitrogen-related policies broken down by policy types (no. of classification) for Pre-2000, 2001-2010 and 2011- 2019**

Source: SANH Database (Yang et al. 2021).

The increasing number of nitrogen-related policies since 2000 certainly indicates a raising environmental concern at the policy level. The above figures depict some significant points viz., in Bangladesh most of the policies do not refer to any environmental sink and have increased over the time. Consequently, sector specific policies (more specifically single sector i.e., agricultural policies) have also grown in numbers over the year. Most of the policies were framework policies, thus lacking in regulatory measures to control nitrogen pollution. Hence, the gaps in policies mostly include lack of integration as well as lacks in concrete environmental measures. However, these also provide scope for further development opportunities through amendments in existing policies and/or formulation of new policies. Multiple sector and sink-oriented policies, in particular multiple-sink policies would ensure that sectoral policies are linked to sinks and consider environmental impacts/costs and have measures to mitigate those impacts.

## 5.2. Analysis of drivers and barriers to sectoral policy change

Among different sectors, agriculture, industry, and transport have shown sharp rise in the level of $N_r$ emission. UNEP and WHRC (2007) reported that in the last 150 years, emission of nitrogen from these three sectors into the global environment has increased more than 10-folds annually. In Bangladesh industry, transport, and agriculture are found to be the major sources/drivers of $N_r$ pollution, emitting larger portions of $N_r$ pollutants and contributing to increased emissions substantially over the years. Table 26 provides an in-depth analysis into the drivers or factors that contributed to rise in $N_r$ emission in the three sectors and the possible barriers to policy change.

**Table 26: Drivers of N emission and Barriers to policy change in Bangladesh**

| Drivers | How it is a $N_r$ driver and policy focuses | Sector Overview | Barrier to Policy change |
|---|---|---|---|
| Agriculture (Crop, fishery, livestock) | • Input intensive green revolution driven crop agriculture, where increasing production is the main motto.<br>• Manifold growth in food demand, largely fuelled by population and economic growth.<br>• Shrinking availability of agricultural land forcing more production from limited land. Less focus on input management and sustainability, resulting in low input use efficiency.<br>• For ammonia ($NH_3$), an ambient air pollutant, agriculture is by far the main pollution source (85% of total emissions in 2015) and emissions from this sector have been steadily increasing. Land use/agriculture is also major contributing source for $N_2O$ emission (Crippa et al. 2019a, 2019b). Hence, measures for sustainable $N_r$ management are urgently required here.<br>• Highest 35% of SANH database classified policies, directly or indirectly related to $N_r$ emission were agriculture sector focused policies. These policies primarily focus on increased productivity for ensuring food security in face of the growing | • GDP contribution (2020-21): 13%.<br>• Around 40% of the total labour force employed.<br>• Nitrogen constitutes about 55% of the total nutrients (combining natural and artificial sources) in food production (BFA 2018)<br>• Agricultural subsidies for 2020-21 (fertilizer and other activities) at USD 1107.4 million. Source: MoF (2021) and BBS (2021)<br>• In Bangladesh, the recovery efficiency of $N_r$ hardly passes beyond 30% in general and hence the rest of the reactive $N_r$ remains in the | • The pollution is largely non-point source (NPs) type of pollution and hence designing, implementation and monitoring of any policy instrument is challenging.<br>• Tracking each farmer and/or retailer's activities, monitoring of N-fertilizer sale at the root level can be difficult while implementing any price and/or quantity ceiling and/or floor.<br>• Many of the policies are vague and do not have a plan for implementation. For instance, many argue for sustainability but do not have concrete measures on how to achieve this. Application of urea in super granule has been advised. But no strategy to promote has been suggested.<br>• Political motivation as well as the preference to attain immediate goals can refrain policy makers from adopting new policies or altering existing policies (Huda and Khan 2014). |

| | | | |
|---|---|---|---|
| | population. Most of these policies are found to be sector focused without referring to environment, particularly $N_r$ (i.e., 58 of 65 agricultural policies did not refer to any environmental sink), despite many (27) of them having high relevance to $N_r$ waste. | environment (Rahman and Biswas 2020).[15] | • Current policy approaches often overlook all the actors in the agri-food chain. Not only is there a steeper focus on farmer behaviour but also omitting a larger section of actors in the agri-food chain can be a challenge for policy makers in capturing the actual $N_r$ status in the environment (Kanter et al. 2020a).<br>• The mind-set of farmers and extension agents which has been shaped for years towards input-intensive farming, is difficult to change. |
| Industry | • Cement, brick industry, unplanned construction works are major sources of air pollution. Also, in Bangladesh power industry is imposing higher threat to the environment by emitting higher $N_r$ each passing year i.e., increased emission from power industry: $NH_3$ by 75%, $NO_x$ by 86% and $N_2O$ by 81% (Crippa et al. 2019a, 2019b).<br>• To accelerate the industrial growth 'National Industrial Policy' was undertaken in 2016. Underlying objectives of the policy include sustainable and inclusive industrial growth through productive employment to create new entrepreneurs, women empowerment and international market linkage.<br>• 'Brick manufacturing and Kiln construction (control) Act 2013' has been formulated to reduce emissions from brick kilns. In last 15 years, the Bangladesh government implemented several mitigation strategies, such as introducing cleaner technologies | According to MoF (2020)<br>• GDP contribution of industrial sector stands at 35% in 2020-21.<br>• Four subsectors are Mining and quarrying, manufacturing, electricity gas and water supply and construction<br>• Among the sub-sectors manufacturing contributes the highest in national GDP (24% in 2020-21)<br>• The fertilizer industry is one of the most important industries in Bangladesh and urea is mostly produced.[16] | • Policies are designed towards increasing production. Sustainability and environmental issues are of secondary concern.<br>• Insufficient equipment and technical manpower for rigorous stack emission monitoring may pose difficulties for efficient implementation of policies<br>• Inadequate emphasis on compliance and environmental standards, monitoring etc. (DoE 2012b).<br>• Inadequate financial incentives or regulatory support can limit sustainable production and renewable energy investment promotion.<br>• Corruption, lack of awareness and/or scepticism (i.e., reluctance to adopt new sustainable technologies) could be |

[15] N uptake by grain and straw/N applied*100

[16] During 2020-21, urea demand in the country was 2,550,000 MT, where domestic production could meet around 26% (MoF2021)

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| | for brick production (VSBK or hybrid Hoffman kilns or zigzag habla kilns) and reducing emissions from vehicles to improve the air quality (ESMAP, 2011; Rahman et al., 2019).<br>• Due to the lack of proper monitoring, there are still unregistered and/or informal traditional brick kilns (DoE, 2019).<br>• Underlying subsectors of the broad industrial sector are major contributors of $N_r$ emissions but the policies lack regulation, standards formulation and proper implementation. | • Tannery sector produces approximately 20,000 $m^3$ of liquid waste and 780,000 ton of solid waste per day (Ahaduzzaman et al. 2017). | barriers to promote new policies and/or alter existing policies (Sarker et al. 2017). |
| Transport | • The transport sector dominates as an air pollution source (11% of $PM_{2.5}$ and 7% of road dust in Dhaka city, NILU (2014)), particularly in major cities like Dhaka, Gazipur, Chattogram.<br>• Motor vehicle, power plants, and fuel burning of any source cause $NO_2$ emissions. Also, vehicle emissions not only cause $NO_x$ and $SO_2$ pollution but are a prime source of PM pollution. Together all of them can cause severe health damage.<br>• A study by the Norwegian Institute for Air Research (NILU) under the CASE project has attributed 10.4% of fine particles to vehicle emission in Dhaka city. In this scenario the government of Bangladesh has revised the car emission standards in 2005 for both new (EURO II standard) and in-use (EURO I standard).<br>• In 2003 Government of Bangladesh replaced the 2-stroke-3 wheeler baby taxies from Dhaka city and introduced CNG (compressed natural gas) that instantly cut down the $PM_{2.5}$ and $PM_{10}$ concentration by 41% and 48% respectively (DoE 2019) | • Transport, storage and communication sector shared 11% of GDP (constant price), within which land transport solely contributed 6.94% in the GDP of Bangladesh during 2020-21 (BBS 2021).<br>• Total number of registered vehicles up to June 2018 had increased by 68% from 2010. Among which number of light duty vehicles increased by 183% during that timeframe.<br>• $NH_3$, $NO_x$ and $N_2O$ emission by transport sector in Bangladesh has undergone the fastest increase by 4,660%, 212% and 501% respectively from 2000 to | • MBI (Market based instrument) or green tax reform, such approaches to control emission require efficient monitoring and good governance, in which Bangladesh may lack and not fully capable due to lack of monitoring sites and/or consistent monitoring reporting process (DoE 2012a).<br>• Limited capacity to enforce the emission standard might pose as a critical barrier to policy change (DoE 2012a). Also monitoring sites majorly focus on large cities whereas vehicles emission is increasing all over the nation.<br>• Improvising and promoting awareness regarding greener and healthier modes of transport and travel (cycling/walking) can be difficult. Roads in major cities are heavily congested. Efforts to improve public transport have had little effect and many people see no viable alternative to |

| | | | |
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| | • Most of the policy approaches in Bangladesh are CAC (command and control), while the CNG conversion was a successful MBI (market-based instrument) approach.<br>• Nitrogen emission was not included as a serious concern compared to PM in transport policies (17 policies classifies as the transport sector in SANH database), although $NO_2$ works as precursor of fine particle and $O_3$ in the atmosphere (DoE, 2012a) | 2015 (Crippa et al. 2019a, 2019b). | the use of cars and taxis (Jamal et al. 2022; Labib et al. 2014).<br>• Corruption makes it difficult to ensure implication of laws and compliance (Sarker et al. 2017). |

## 6. Stakeholder Overview

Stakeholders in this report are defined as individuals or groups who have an interest and/or potential influence on $N_r$ management. This includes a wide range of actors (both government and non-government) due to the multi-sector sources of $N_r$ pollution with its potential impact on human and the environment. Table 27 provides a preliminary overview of some of the primary groups who may have roles in $N_r$ management. Also, some important policies for responsible stakeholders are listed, based on high/medium relevance and impact scope. SANH will continue to develop a better understanding of the nitrogen-relevant stakeholders over the course of the project.

**Table 27: Preliminary Stakeholder Overview**

| Name of the ministry | Number of $N_r$ related policies | Important policies | Other important stakeholders |
|---|---|---|---|
| Ministry of Agriculture | 35 | National Agriculture Policy<br>National Organic Agriculture Policy, 2016<br>Fertilizer Management Act, 2006 | Bangladesh Agricultural Development Corporation (BADC)<br>Bangladesh Agricultural Research Institute (BARI)<br>Bangladesh Rice Research Institute (BRRI)<br>Department of Agricultural Extension (DAE)<br>Bangladesh Agricultural Research Council (BARC)<br>Department of Agricultural Marketing (DAM)<br>Bangladesh Fertilizer Association (BFA) |
| Ministry of Fisheries and Livestock | 31 | National Poultry Development Policy, 2008<br>National Fisheries Strategy, 2006<br>Animal Feed Rule, 2013 | Department of Livestock Services<br>Department of Fisheries<br>Bangladesh Livestock Research Institute (BLRI)<br>Bangladesh Fisheries Research Institute (BFRI) |
| Ministry of Food | 13 | National Food Policy, 2006<br>The Food Safety Act, 2013 | Ministry of Agriculture<br>Department of Livestock Services<br>Department of Fisheries |
| Ministry of Land | 7 | National Land Use Policy, 2001 | Land Reform Board |
| Ministry of Industries | 9 | National Industrial Policy, 2016 | Bangladesh Chemical Industries Corporation (BCIC)<br>Bangladesh Small and Cottage Industries Corporation (BSCIC)<br>Bangladesh Standard and Testing Institute (BSTI) |

| Name of the ministry | Number of $N_r$ related policies | Important policies | Other important stakeholders |
|---|---|---|---|
| Ministry of Power, Energy and Mineral Resources | 15 | National Energy Policy, 2004 | Power Division<br>Energy and Mineral Resources Division |
| Ministry of Water Resources | 11 | Coastal Development Strategy, 2006<br>The Water Resource Planning Act, 1992 | Bangladesh Water Development Board<br>River Research Institute<br>The Centre for Environmental and Geographic Information Services (CEGIS) |
| Ministry of Road Transport and Bridges | 8 | Motor Vehicles Ordinance, 2018<br>BRTA: Bangladesh Road Transport Authority Law, 2017 | Roads and Highways Department<br>Bangladesh Road Transport Authority (BRTA)<br>Bangladesh Road Transport Corporation |
| Ministry of Railways | 1 | Master Plan of Bangladesh Railway, 2018 | Bangladesh Railway |
| Ministry of Shipping | 7 | National Shipping Policy, 2000 | Bangladesh Inland Water Transport Authority<br>National River Protection Commission<br>National Maritime Institution |
| Ministry of Civil Aviation and Tourism | 3 | Civil Aviation Act, 2017 | |
| Ministry of Local Government, Rural Development and Co-operatives | 3 | National Rural Development Policy 2001 | Local Government Engineering Department (LGED)<br>Department of Public Health Engineering |
| Ministry of Planning | 5 | Bangladesh Delta Plan, 2100 | Bangladesh Institute of Development Studies (BIDS) |
| Ministry of Environment, forest and climate change | 33 | Bangladesh Environment Conservation Act, 1995<br>National Environment Policy, 2018<br>Environment Conservation Rules, 1997 | Department of Environment (DoE)<br>Bangladesh Forest Department |
| **Other stakeholders beyond government: Universities, civil societies, international, regional and local non-government organizations** | | | |
| **International Organizations/agencies/donor:** United Nations (UNDP, UNEP, FAO, United Nations World Food Programme (WFP), World Health Organisation (WHO), Development Banks (World Bank, Asian Development Bank), Donor institutes (USAID, DFID, JICA), International Organization World | | | |

| Name of the ministry | Number of $N_r$ related policies | Important policies | Other important stakeholders |
|---|---|---|---|
| Green Climate Association, International Union for Conservation of Nature (IUCN), International Rice Research Institute (IRRI), Climate and Clean Air Coalition (CCAC) | | | |
| **Regional Partnership:** South Asian Association for Regional Cooperation (SAARC), South Asia Cooperative Environment Programme (SACEP) | | | |
| **Non-government Organization:** Bangladesh Environment and Development Society (BEDS), CEDAR NGO, Works for Green Bangladesh, Environment and Social Development Organization, Bangladesh Environmental Lawyers Association (BELA), CARE Bangladesh, BRAC, TMSS, etc. | | | |
| **Universities:** Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh University of Engineering and Technology (BUET), Bangladesh Agricultural University (BAU), Dhaka University (DU), etc. | | | |
| Other: Gas transmission and distribution companies, Bangladesh Bank (Ministry of Finance), City Corporations, Fertilizer companies (Ashuganj Fertilizer and Chemical Company Limited, Chittagong Urea Fertilizer Limited, Jamuna Fertilizer Company Limited, Karnaphuli Fertilizer Company Limited, Shahjalal Fertiliser Factory, etc.) | | | |

## 7. Case Studies of Significant Nitrogen Control Policies

Policies that addressed multiple sinks and/or sectors, contain multiple policy types and sources are best suited to face the multidimensional nitrogen related issues. Policies that were classified as having positive impact direction (44%) emphasised addressing and mitigating environmental pollution, whereas policies with mixed/neutral impact direction (37%) focused on economic growth, combining with environmental implications at varying levels. Among the 187 classified policies in Bangladesh, three policies were selected for further discussion because of their high relevance, large impact scope and potential scope for the $N_r$ management. These policies are 'National Environment Policy, 2018', the 'Organic Agriculture Policy, 2016' and the 'Fertilizer Management Act, 2006'. Each policy is described in more detail below.

'National Environment Policy, 2018' was formulated in order to protect the environment, conserve wildlife, control environmental pollution and deal with the adverse impacts of climate change. It was framed to guide the implementation of environmental laws and other activities to ensure a sustainable environment by enabling collaborative approaches between all related government and non-government organizations. The policy includes measures not only to set effective environment-friendly systems for multiple sectors but also to address multiple environmental sinks. The policy is multisectoral and has integrated objectives and approaches towards sustainable environmental management.

Another notable policy is the 'Organic Agriculture Policy, 2016', an agricultural sector-oriented policy that primarily deals with sustainable and organic farm production while focusing on mitigating pollution from chemical fertilizers' usage. It was developed to bind the development activities through sustainable approaches. Although sector-oriented, the policy addresses multiple environmental sinks and is classified as having positive impact direction along with high $N_r$ relevance.

The 'Fertilizer Management Act, 2006' has the potential to address the environmental management of $N_r$ as it specifically deals with chemical fertilizer sales, production and import, distribution and usage. Although it has the scope for including environmental pollution (e.g., $N_r$ pollution by overusing Urea) from multiple angles (e.g., pollution during production, application in fields and/or management while distribution), it has mainly focused on fertilizer production and distribution with little reference to the environment. Hence, the policy was classified as having a negative impact direction despite having direct relevance to $N_r$ management.

**Case study 1:** National Environmental Policy

| | | | |
|---|---|---|---|
| **Title** | National Environmental Policy | | |
| **Type of text** | Policy | **Sink** | Multiple |
| **Year** | 2018 | **Sector** | Multiple |
| **Spatial scale** | National | **Policy type** | Multiple |
| **Responsible ministry** | Ministry of Environment, Forest and Climate Change | **Impact direction** | Positive |
| | | **$N_r$ relevance** | Direct |
| Policy Mission/Goal | Ensuring sustainable development by protecting the environment, controlling pollution, conserving biodiversity and tackling the adverse impacts of climate change. | | |
| Policy Objectives | • Expansion of adaptation activities to reduce the adverse effects of climate change<br>• Encouraging the procurement and introduction of low carbon emissions technology in Bangladesh<br>• To identify and control all types of pollution and degradation in the environment<br>• Unveiling and expanding areas of mutual cooperation in regional and international arenas for global environmental development<br>• Ensuring environment friendly development in all sectors<br>• Public-private partnership for environmental development<br>• Ensuring Environmental Impact Assessment and Strategic Environmental Assessment, where necessary | | |
| Relevance to $N_r$ | The policy is environment driven and focuses on mitigating pollution in any form that occurs by activities in different sectors and pollutants from any sources, mostly including nitrogen in various forms ($NO_2$, $NH_3$ and/or, $N_2O$, etc.) | | |
| Policy Evidence | • The policy focuses on sustainable environmental management through pollution control, bio-diversity conservation and tackling climate change impacts through Public-Private collaboration but the approaches are generalized rather than mentioning any specific activities or measures.<br>• Again, the policy does not mention concrete and coherent approaches for different environmental issues (e.g., pollution and climate change) though these issues are often interlinked and cause adverse environmental effects.<br>• It has scope to incorporate specific measures for pollution control by focusing on different forms of pollutants (e.g., $N_r$ pollutants, $PM_{2.5}$, $PM_{10}$, carbon etc.) and their interrelationships for better management of the environment | | |

**Case study 2:** Organic Agriculture Policy

<table>
<tr><td>Title</td><td colspan="3">Organic Agriculture Policy</td></tr>
<tr><td>Type of text</td><td>Policy</td><td>Sink</td><td>Multiple</td></tr>
<tr><td>Year</td><td>2016</td><td>Sector</td><td>Agriculture</td></tr>
<tr><td>Spatial scale</td><td>National</td><td>Policy type</td><td>Multiple</td></tr>
<tr><td rowspan="2">Responsible ministry</td><td rowspan="2">Ministry of Agriculture</td><td>Impact direction</td><td>Positive</td></tr>
<tr><td>N relevance</td><td>Direct</td></tr>
<tr><td>Policy Mission/Goal</td><td colspan="3">The mission is to manage agriculture by reducing the use of agrochemicals and maintaining soil fertility by addressing the physical, chemical and biological properties of soil</td></tr>
<tr><td>Policy Objectives</td><td colspan="3">• Maintaining soil fertility organically<br>• Identifying areas, places and crops for organic farming<br>• Ensuring the production and availability of organic resources e.g., seed, manure etc.<br>• Increasing efficiency regarding organic farming techniques<br>• Identification of traditional and indigenous knowledge and practices consistent with organic farming and involving with production activities<br>• Establishing the standards for organic farming and ensuring certification of organic produces<br>• Establishing the national and international market for organic produces i.e., both inputs and outputs</td></tr>
<tr><td>Relevance to $N_r$</td><td colspan="3">The policy focuses on ensuring institutional control by improvising a taskforce for organic standardization, monitoring and implementation of rules and regulations. To maintain soil fertility, it emphasizes using natural resources e.g., soil organic matter and micro-organisms, compost, organic fertilizers, poultry and farm manure, instead of harmful chemicals (that involves fertilizers e.g., Urea, DAP, and MOP). It also focuses on environment-friendly and pollution-free irrigation e.g., using rain/ flood water, or renewable energy. Such an approach to dealing with chemical fertilizers, pesticides and/or, pollution-free farm techniques is strongly relevant to $N_r$ management</td></tr>
<tr><td>Policy Evidence</td><td colspan="3">• The policy will help to keep up with the increased national and global demands for organic products. Also, it can help to capture the global market with healthy and harmless agricultural produces. It is also important for improved public health and reduction of soil degradation caused by agrochemicals along with environmental sustainability.<br>• It neither mentions any specific measures/rules/regulations on how to implement the ideas on field nor discusses any concrete quantity of fertilizers (i.e., organic-inorganic).</td></tr>
</table>

**Case study 03:** Fertilizer Management Act

| **Title** | Fertilizer Management Act | | |
|---|---|---|---|
| **Type of text** | Legislation | **Sink** | Non-applicable |
| **Year** | 2006 | **Sector** | Agriculture |
| **Spatial scale** | National | **Policy type** | Multiple |
| **Responsible ministry** | Ministry of Agriculture | **Impact direction** | Negative |
| | | **N relevance** | Direct |
| Policy Mission/Goal | The mission is to control the production, import, transportation, storage, distribution and sale of Fertilizers and related products to be used in agriculture | | |
| Policy Objectives | Establishment of National Fertilizer Standardization Committee in order to<br>1. Make suggestions to the government regarding the collection, distribution, storage and sale of fertilizers<br>2. Standardize chemical and organic fertilizers, bio-fertilizers, soil amendments and plant growth stimulators, and to help the government decide about the quantities to be collected, distributed, stored and sold<br>3. Make suggestions and help the government regarding standardization of fertilizers, approval of fertilizer formulation methods, licensing of dealers etc.<br>4. Ensure proper monitoring of fertilizer import, production, sale and distribution in terms of certification of permission<br>5. Ensure proper enforcement of rules and regulation and punishment in case of violation.<br>6. Emphasize monitoring and control regarding misbranding, adulteration etc. | | |
| Relevance to N | Since the policy addresses the management of different fertilizers, more specifically chemical fertilizers (Urea, Di Ammonium Phosphate etc.), it has a high relevance to nitrogen emissions. | | |
| Policy Evidence | • Although any activities related to chemical fertilizer (production/distribution/import/field application) require attention towards the environment, the policy does not mention anything related to N management. Hence, its impact direction is negative. Also, the policy emphasises the adequacy of quality fertilizer through production and import rather than controlling its uses.<br>• The amendment of some selective sections in 2018 mentioned environmental safety during fertilizer production/application but did not concretely specify measures related to nitrogen pollution or any pollution management.<br>• Being a policy on fertilizer, it has scope for incorporating environmental concerns (e.g., nitrogen pollution through Urea fertilizer) and addressing better pollution management (e.g., concrete regulations in fertilizer application). | | |

## 8. Recommendations

- Although there are environment focused policies, some of them were formulated a long time ago and might require revision/updates for better $N_r$ management according to current standards.
- Nitrogen policy development requires an inclusive stakeholder input to consider different perspectives as a foundation for durable change.
- Measures proposed in the NDC (and other key ambitious policy documents) must be monitored to ensure full implementation to combat GHG and air pollutants.
- Regional/international commitments such as support of UNEA5.2 and following this to UNEA6 to sustainably manage nitrogen must be strengthened.

**Multi-sectoral and integrated policies**

Interactions between sectors need to be considered alongside potential impacts on environmental sinks. Likewise sink focused policies, such as air quality, soil, climate, ecosystems, and water are best placed when they identify the risks from sector-based activities with options to mitigate adverse impacts. UNEP (2019b) advises, in science and policy, a multi-source, multi-sector perspective will allow synergies and trade-offs to be better understood. In addition, a holistic, integrated and coherent approach is required to address the global challenge of managing nitrogen effectively and efficiently. Moreover, 'smart regulation'¸ the use of multiple rather than single policy instruments, and a broader range of regulatory actors, will also produce better regulation outcomes (Gunningham and Sinclair 1998).

In Bangladesh only nine policies address both multiple sinks and multiple sectors, although there are many policies directly or indirectly relevant to nitrogen. For example, 'Environment Conservation Rules 1997', 'National Environment Policy 2018' and 'Bangladesh Delta Plan 2100' are policies classified as addressing multiple sinks and sectors and are considered to be in a better position to deal with nitrogen management. Sector-specific policies are growing in number over the years in Bangladesh, particularly since 2000, which is potentially an advance towards addressing policy gaps resulting from a lack in sink orientation and integrated objectives. Again, not only agriculture but also several other sectors (e.g., transport and industry) are potentially emerging sectors and must be considered for future $N_r$ management.

Most policies in Bangladesh are framework policies and there is a limited number of core regulatory policies, which are needed to complement broader integrated policy framework policies, e.g., establishing $N_r$ emission standards for water and air. Although there are some guidelines, they do not address $N_r$ pollution issues prominently. Also, policies mostly focus on a single compound, with $NO_x$ being the most problematic of the three $N_r$ compounds (in terms of overall amounts and growth). Nonetheless, nitrogen compounds should not be dealt with in isolation of each other. Certain $N_r$ compound mitigation measures may cause a negative knock-on to other compounds. Moreover, the formulation of nitrogen policy should ideally be evidence-based requiring research and development and data and methods to evaluate and monitor $N_r$ emissions and test and evaluate mitigation options. Increasing the number of relevant policies for R&D /data and methods would be recommended across the range of sectors.

**Nitrogen specific policy (amendment and introduction)**

Nitrogen emissions have been increasing over the time in Bangladesh, but very few policies address the problem concretely. Out of 187 nitrogen related policies, 96 (51%) policies were classified to be directly and highly relevant to nitrogen management. For instance, 'National Environmental Policy 2018' and 'National Industrial Policy 2016' have directly addressed environmental pollution and mitigation, more specifically mentioning carbon emissions. However, these do not specify $N_r$ pollution and mitigation directly, yet $N_r$ emissions are posing significant threats to the environment. Hence, core policies specified towards nitrogen management can be formulated or existing policies can be altered to promote better nitrogen management by more direct actions. Also, evidence of actual policy impacts on $N_r$, whilst outside the scope of this study, would be necessary to determine how those policies work in practice. All the policies require further scrutiny to determine effectiveness linking proposed objectives to actual impacts.

Some policies do not refer to environmental considerations, despite having potential $N_r$ impacts. Such policies, classified as negative in impact, indicate a potential policy gap, hence greater focus on other environmental aspects, e.g., $N_r$ management, would be an advantage. As mentioned by DoE (2012a), one of the major approaches in pollution control is to ensure the 'polluter pays' principle, that can be enforced properly through MBI approaches. Hence, employment of a mix of CAC and MBI approaches to control $N_r$ pollution, depending on the suitability for the country and specific sources, is recommended. Based on sectoral impacts on the environment, and specifically focusing on $N_r$ management, measures can be adopted for specific sectors. Environmental policy in general recognizes either point source or NPS but it is beneficial to consider both, since, considering both sources indicate a better understanding of how $N_r$ enters the system and also helps in undertaking relevant actions.

**Market-based policy intervention**

A general guideline for promoting products those are produced maintaining environmental guidelines can be developed. The entities maintaining environmental standards can be supported through Environmental Policy Instrument. For this, proper designing and implementation of compliance must be ensured (e.g., by increasing the number of core regulatory and economic regulation policies). Above all, the demand side can play a vital role to raise awareness about environmental safety in the production process.

**Sector specific policy recommendations**

| | |
|---|---|
| Agriculture | • Continue rebalancing fertilizer policy, e.g., reducing urea subsidies and promoting funding on sustainable practices<br>• Subsidy for briquette urea<br>• Extension and training<br>• Action-based research for climate-smart agriculture technology development and adoption |
| Industry | • Energy-efficient incentives like improved cooking stoves, or brick kilns should be addressed and specific measures should be taken to ensure implementation<br>• Department of Environment can play the central role in standards formulation, proper monitoring and control through a pollution index (Ahaduzzaman et al. 2017)<br>• Integrated regulatory policies need to be complemented by more specific actions. e.g., industrial emission standards<br>• Action-oriented policies are needed (e.g., promoting less nitrogen-emitting technology) and/or guidelines to enforce rules and/or laws for different sub-sectors at national, sub-national level to promote less industrial emission |

| | |
|---|---|
| Transport | • Intervention to improve market structure towards a more competitive one through empowering the demand side and enabling ease of entry for environment-friendly sustainable enterprises<br>• Since Bangladesh mostly imports vehicles (DoE 2012a), specific measures on emission control for not only carbon but also other emissions like $PM_{2.5}$, $PM_{10}$, and $N_r$ prior to import are required (e.g., emission certificate before importing). Although NDC has emphasized the use of electric and hybrid vehicles over private cars considering environmental betterment (MoEFC 2021), more specific plans and actions are still required.<br>• More nitrogen specific strategies and/or policies should be developed to control GHG (greenhouse gases) and $N_r$ emission (e.g., emission-based registration fees, banning old vehicles more than 15 years)<br>• More research and development-based guidelines on which vehicles to be permitted for environmental sustainability (e.g., promoting electric vehicles, DoE 2012a) |

In summary, all the nitrogen-related policies collected and analysed in this report would benefit from further scrutiny to determine their effectiveness, their actual impacts on Nr management, such as identifying whether a policy may contribute to point source, or non-point source pollution, or both. Likewise, it is important to evaluate further the barriers and opportunities for addressing $N_r$ waste in current policy. Further in-depth research on the impact of policies and stakeholders related to $N_r$ management would further support policy development. SANH will continue researching policies and stakeholders over the course of the project (2022-24) to improve national and regional level understanding of the nitrogen policy landscape.

Science-based decision-making is crucial for achieving the sustainable management of nitrogen and to reduce Nr waste. SANH is supporting South Asia in its journey in building the scientific evidence of the sources, causes, emission and mitigation measures along with the development of national nitrogen budgets mapping the scale and significance of Nr. SANH is working on improving the scientific and technical base that will strengthen the ability of countries such as Bangladesh to achieve their commitments to sustainably manage nitrogen and develop its nitrogen National Action Plan preparing the way for UNEA-6.

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# Appendix

## Appendix Section 01

**Appendix Table 1. Ammonia ($NH_3$) total emissions for 2000 and 2015 (Gg) and percentage change for different sectors between 2000 and 2015, in Bangladesh**

| IPCC | IPCC description of sectors | 2000 | 2015 | % change (2000-2015) |
|---|---|---|---|---|
| 1.A.1.a | Main Activity Electricity and Heat Production | 0.06 | 0.24 | 300 |
| 1.A.1.bc | Petroleum Refining - Manufacture of Solid Fuels and Other Energy Industries | 0.00 | 0.00 | - |
| 1.A.2 | Manufacturing Industries and Construction | 0.06 | 0.07 | 16.67 |
| 1.A.3.b_noRES | Road Transportation no resuspension | 0.02 | 0.92 | 4500 |
| 1.A.3.c | Railways | 0.00 | 0.00 | - |
| 1.A.3.d | Water-borne Navigation | 0.00 | 0.00 | - |
| 1.A.4 | Other Sectors | 55.02 | 67.47 | 22.63 |
| 1.A.5 | Non-Specified | - | - | - |
| 1.B.1 | Solid Fuels | 1.96 | 2.40 | 22.45 |
| 2.B | Chemical Industry | 4.57 | 2.44 | -46.61 |
| 2.D | Non-Energy Products from Fuels and Solvent Use | - | - | - |
| 3.A.2 | Manure Management | 36.46 | 56.63 | 55.32 |
| 3.C.1 | Emissions from biomass burning | 13.27 | 16.26 | 23 |
| 3.C.3 | Urea application | 47.42 | 54.34 | 15 |
| 3.C.4 | Direct $N_2O$ Emissions from managed soils | 225.79 | 300.62 | 33 |
| 4.C | Incineration and Open Burning of Waste | 0.02 | 0.02 | 0 |
| 4.D | Wastewater Treatment and Discharge | 0.63 | 0.80 | 27 |

Source: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a).

**Appendix Table 2. Nitrogen oxides (NOx) emission in 2000 and 2015 and percentage change for different sectors between 2000 and 2015, Bangladesh (tonnes/year)**

| IPCC code | IPCC description of sector | 2000 | 2015 | % change |
|---|---|---|---|---|
| 1.A.1.a | Main Activity Electricity and Heat Production | 32.10 | 221.91 | 591.31 |
| 1.A.1.bc | Petroleum Refining - Manufacture of Solid Fuels and Other Energy Industries | 0.65 | 0.64 | -1.54 |
| 1.A.2 | Manufacturing Industries and Construction | 16.32 | 74.71 | 357.78 |
| 1.A.3.b_noRES | Road Transportation no resuspension | 24.53 | 83.78 | 241.54 |
| 1.A.3.c | Railways | 5.46 | 14.60 | 167.40 |
| 1.A.3.d | Water-borne Navigation | 11.98 | 32.59 | 172.04 |
| 1.A.3.e | Other Transportation | - | - | - |
| 1.A.4 | Other Sectors | 25.87 | 37.65 | 45.54 |
| 1.A.5 | Non-Specified | - | - | - |
| 1.B.1 | Solid Fuels | 0.03 | 0.04 | 33.33 |
| 1.B.2 | Oil and Natural Gas | - | - | - |
| 2.B | Chemical Industry | 1.52 | 0.77 | -49.34 |
| 2.H | Other | 0.02 | 0.05 | 150.00 |
| 3.A.2 | Manure Management | 1.55 | 2.16 | 39.35 |
| 3.C.1 | Emissions from biomass burning | 13.70 | 16.59 | 21.09 |
| 3.C.4 | Direct $N_2O$ Emissions from managed soils | 24.39 | 33.50 | 37.35 |

Source: data was sourced from EDGAR v5.0 Global Air Pollutant emissions from Crippa et al. (2019a).

**Appendix Table 3. Classifications used in the SANH policy analysis approach**

| Classification | Codes | Description |
|---|---|---|
| **Sink** | Water; Air; Climate; Soil; Ecosystem; Multiple (if more than one sink was referred to); & Not Applicable (NA) (if no sink was referred to). | if the policy objective or content mentioned one or more sinks. Classifications were not based on assumed links or impacts. A sink refers to a reservoir that takes up a nitrogen or, where nitrogen loads can accumulate and can have an 'impact'. |
| **Sector** | **Main sectors:** Agriculture; Energy; Food; Industry; Land Use Change; Transport; Urban Development & Tourism; Waste; Other; Multiple; Not Applicable (NA). | Policies were coded to a main sector, where possible, they were also coded to a sub-sector, indicating the specificity of a policy. If the policy covered multiple sub-sectors, categorising as a main sector was sufficient. |
| **Policy type** | Regulatory | Policies that set quantifiable limits or restrictions on N production, consumption and loss. This could also include broader strategies if they include quantifiable targets that could have impacts on N management. |
| (Policies could include multiple policy instruments, therefore policies could be coded under one or more of these codes as appropriate.) | Economic | Policies that use financial incentives and signals to spur quantifiable improvements in N management and N mitigation'. Following Kanter et al. (2020) *regulatory* and *economic* policies were classified as 'core' policies, e.g. those most likely to have an impact on N production, consumption of management. |
| | Framework | Broad objectives relevant to N pollution with no quantifiable constraints and/or delegation of authority for N policymaking to another governing body'. A number of indirectly relevant policies fell under this definition. For example, it could be a regulatory policy, but in the absence of direct quantifiable constraints on nitrogen it would be classified as a 'framework' as in the case of the Regulations on Safe Food (Healthy Environment Protection), from Bangladesh. |
| | Data and methods | Those that 'establish data collection and reporting protocols for various aspects of N pollution but do not set environmental standards or enforce them'. This would also include standards (which could in addition be classified as regulatory). Policies that refer to an objective and/or actions for Monitoring and evaluation (M&E) were also classified under this |

| | | |
|---|---|---|
| | Research & Development (R&D) | Policies that allocate funding for R&D both into the effects of N pollution on the environment and human health and into new technologies that could improve N management'. A policy could be classified under this code if it referred to promoting research in the text and that research relates to N related practices |
| | Commerce | Policies that regulate an aspect of the business environment surrounding N production and consumption'. |
| | Pro-N | Policies that lower the price of N production and consumption via government aid or other means, usually incentivizing higher farmer-level N use' |
| **Pollution type** | Point source | *Point source pollution* is where nitrogen pollution is discharged directly into water or into the atmosphere at a 'discrete point', making it easier to control and monitor. A policy would be classified as this if it states actions to target/control/measure point source pollution. |
| | Non-point source | *Non-point sources* covers pollution that comes from many land, air or water sources and can be carried overland, underground, or in the atmosphere, making them difficult to measure and control (Islam et al. 2018; Liu et al 2020).<br>A policy would be classified as this if it states actions to target/control/measure non-point source pollution. |
| | Both | Policies refer targeting both point and non- point source pollution |
| | Unspecified | For policies that do not reference or recognise the different types of N pollution sources, and do not specify any intention/ measure/control pollution from either of those source types. |
| | NA | The default classification for Policies classified with a *negative* impact direction, and/or as having an *indirect relevance* received. |
| **Impact direction** | Positive | A policy was coded with 'positive' impact if it promoted a reduction in N pollution and/or improved nitrogen management whether directly or indirectly. This would likely include policies that were environmentally oriented such as; environmental standards, and water quality control policies. |
| | Mixed/ neutral | Policies coded 'mixed neutral' if it could do both, e.g., aiming to enhance food production but also considering environmental impacts, or if the policy is potentially neutral in its impacts |
| | Negative | A policy that could potentially cause excess nitrogen, such as those that promote synthetic fertiliser use or fossil fuels, would be coded as 'negative' e.g. promotion of fossil fuels |
| **Impact scope** | Large | This classification was for distinguishing the scale of 'possible' impact a policy could have on N use.<br>A *'large'* scope would include nation-wide policies such as an agricultural policy with wide implications for N management. |
| | Medium | *Medium* scope would include those that may encompass a large area (national) but have fewer implications for N management, or sub-national level but large implications for N management. For example, national food and security policies, or a provincial Forest Act |
| | Small | Policies with a *small* scope include smaller spatial areas than provincial, and may be area/zone specific, and/or with minor implications for N management, e.g., plant quarantine rules |

| | | |
|---|---|---|
| **Relevance** | High (direct) | For high and direct relevance to N, 29 key words were used to identify policies, e.g., if the policy contained one or more of these listed key words[17]. |
| | Medium (indirect) | Those classified with 'medium' relevance included 'indirect policies' that still had clear relevance to nitrogen, but did not contain the key words. |
| | Low (indirect) | Policies classified with 'low' relevance include those policies more distantly related to N management such as 'seed' policies or road expansion policies. These policies did not contain any key words or related synonyms but could have indirect knock-on implications for N pollution. For example road expansion policies that encourage more cars, thus leading to increases in $NO_x$ emissions, unless mitigated by other policy initiatives and measures. |

[17] **Key words:** fertilizer, manure, N, N pollution, nutrient pollution, nitrate, nitrates, ammonia, N oxides, nitrous oxide, $N_2O$, $NH_3$, $NO_3$, $NO_x$, eutrophication, hypoxia, air quality, air pollution, emissions, groundwater quality, groundwater pollution, freshwater quality, freshwater pollution, water quality, ozone depletion, climate change, greenhouse gas, agrochemical and effluent.

## Appendix section 02

- **Cross comparatives policies (sinks vs sector, policy type vs sink, policy type vs sector)**

Cross comparison of policies by the classifications helps to better identify their strengths and weaknesses in promoting sustainable $N_r$ management. This section the policies are cross compared by classifications for sink and sectors, policy type and sink and policy type and sectors.

i. Policies by sink and sector

Appendix Table 5 illustrates the sector and sink policy results. Favourable combination includes policies having multiple sectors and sink as they indicate 'integrated objectives' that consider the environment as well as multiple sectors. But the percentage of this combination was found to be quite low (5%) in Bangladesh. This includes policies like, 'National Environmental Policy 2018', 'Coastal Zone Policy 2005' etc.

Most common combination was sector-specific agricultural policies without referring to any sink (31%). Such combination would grab benefit from further review and probable adjustments to mitigate negative externalities. Similar kind of advantage would adhere to the policies with multiple sectors but have not considered sinks, which include 5% of Bangladesh's policies. For example, 'National Rural Development Policy 2001', 'National Sustainable Development Strategy (2010-2021)'.

**Appendix Table 4. Percentage of Nitrogen-related policies by sink and sector, from Bangladesh**

| Sink | Agriculture | Waste & Waste Water | Industry | Food* | Energy | Transport | Land Use Change and Forestry* | Other* | Multiple | No sector included | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Air | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 |
| Water | 1 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 6 |
| Climate | 0.5 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 1 | 2 | 4 |
| Ecosystem | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 2 | 7 |
| Multiple | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 3 | 10 |
| No sink included | 31 | 2 | 3 | 7 | 8 | 9 | 5 | 3 | 5 | 0 | 73 |
| Grand Total | 35 | 2 | 4 | 7 | 9 | 9 | 7 | 3 | 13 | 10 | 100 |

Source: SANH Database (Yang et al. 2021).

The second most common combination was sector specific transport policies without referring to any sinks (9%). The combination has the scope of improvement through further reconsideration on environmental aspect, since transport sector is one of the most responsible causes of air pollution. The 'Motor Cycle Industry Development Policy 2018' and 'BRTA: Bangladesh Road Transport Authority Law, 2017' are good examples. Energy sector-specific policies without considering any sink accounted for around 8% of the total policies, whereas those referring to sink- and sector- specific food policies were 7% of policies in Bangladesh.

Sink specific policies without referring to sectors were low in percentage among which the highest 4% policies were for environmental sink 'water', e.g., 'Bangladesh Water Rules' and 'National Water Management Plan Development Strategy'.

ii. Policies by policy type and sink

Appendix Table 6 depicts the policy type and sink classifications for nitrogen related policies in Bangladesh. The most prominent combination was sector oriented (no sink included) framework policies (44%), followed sector focused research and development policies (15%). Such policies include 'Bangladesh Agricultural Development Corporation Act, 2018', 'Seed Act-2018', and 'National Crop and Forest Biotechnology Policy-2012'. Such policies have scope for further development through reconsideration of the environmental impact of the associated sectors and also could have better implications for $N_r$ management.

Multiple sinks had the next higher percentage combining with framework policies. Meanwhile among the single sink and type combinations framework policies with water as sink constituted relatively the highest 4% of total policies. Rest of the combinations of policy type and sink range from 0 to 3%.

**Appendix Table 5. Percentage of classifications by policy type and sink for Bangladesh's nitrogen-related policies**

| Sink | Regulatory | Economic | Framework | Data and methods | R&D | Commerce | Pro-N | Total |
|---|---|---|---|---|---|---|---|---|
| Air | 0.4 | 0 | 0.4 | 0 | 0 | 0 | 0 | 1 |
| Water | 0 | 0 | 4 | 1 | 2 | 0 | 0 | 6 |
| Climate | 0 | 0 | 3 | 1 | 1 | 0 | 0 | 4 |
| Ecosystem | 0.4 | 0 | 5 | 0 | 1 | 0 | 0 | 6 |
| Multiple | 1 | 0 | 6 | 1 | 3 | 0 | 0 | 11 |
| No sink included | 3 | 1 | 44 | 4 | 15 | 3 | 0.4 | 71 |
| Grand Total | 4 | 1 | 61 | 8 | 23 | 3 | 0.4 | 100 |

Note: The percentage is calculated from the total number of classifications (i.e., 279) and not the total number of policies. This is because one policy could have multiple policy types.
Source: SANH Database (Yang et al. 2021).

Multiple sink-oriented policies mostly included framework, R&D policies. Also, to some extent regulatory and data and methods policies were oriented towards multiple environmental sinks. Policies focusing on multiple environmental sinks while comprising variable policy types, are preferable for sustainable $N_r$ management because of their integrated and objectives and approaches.

iii. Policies by policy type and sector

Appendix Table 6 compares the classifications of policies by sectors and policy types. Framework policies focusing on agricultural sector dominants among all the single sectors combination (20%), followed by R&D (9%) and sink oriented (no sector included) framework policies (6%). Single sector-oriented framework policies including transport (6%), energy (5%), land use and urban development (5%) were relatively higher in percentages compared to other single-sectoral combinations. As with sectors, most combinations indicate a low percentage at ≤4 %.

Multiple sectors were linked to some certain policy types including framework (8%), R&D (4%), data and methods (1%) and regulatory (1%). These multi-sectoral policies associated with multiple policy types are the most suitable policies for better $N_r$ management.

**Appendix Table 6. Percentage of classifications by policy type and sector for Bangladesh nitrogen-related policies**

| Sectors | Regulatory | Economic | Framework | Data and method | R&D | Commerce | Pro-N | Total |
|---|---|---|---|---|---|---|---|---|
| Agriculture | 2 | 0 | 20 | 3 | 9 | 1 | 0 | 37 |
| Waste and waste water | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Industry | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 4 |
| Food* | 0 | 0 | 4 | 0 | 1 | 0 | 0 | 7 |
| Energy | 0 | 0 | 5 | 0 | 2 | 1 | 0 | 8 |
| Transport | 0 | 0 | 6 | 0 | 1 | 0 | 0 | 8 |
| Land use change and forestry | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 6 |
| Urban development & tourism | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 3 |
| Multiple | 1 | 0 | 8 | 1 | 4 | 0 | 0 | 14 |
| No sector included | 0 | 0 | 6 | 2 | 3 | 0 | 0 | 12 |
| Total | 4 | 1 | 61 | 8 | 23 | 3 | 0 | 100 |

Source: SANH Database (Yang et al. 2021).