Maldives Nitrogen Policy Report:

Scientific Evidence, Current Initiatives and Policy Landscape

The Maldives National University (MNU) | South Asian Nitrogen Hub (SANH)

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Foreword

This report, prepared by the Maldives National 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 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.

Professor Mark Sutton
Director UKRI GCRF South Asian Nitrogen Hub
Edinburgh, April, 2022

Foreword

With its unique geography and fragile environment, Maldives is one of the most vulnerable countries in the world. All aspects of the environment (including water, land, and air) are being adversely affected and are facing a steady decline. Industries, businesses, and individuals are facing the economic repercussions that have emerged from the many factors of environmental decline. It is also believed that Nitrogen pollution is the cause of detrimental health impacts, most of which are unknown as it is not yet being monitored or assessed.

Sustainable Nitrogen management requires a review of the Nitrogen status and targeted strategic actions at National and local levels, in collaboration and cooperation between institutions, businesses, and communities. To this end, it is imperative to review the existing strategies and plans and to incorporate and/or address Nitrogen use efficiency and management in the sector plans.

To overcome this Nitrogen challenge for a healthier planet, the South Asian Nitrogen Hub (SANH) Project aims to bring together experts from over 32 leading research organisations from across South Asia and the United Kingdom, including The Maldives National University (MNU). SANH is also working with South Asian governments to further develop policies on Nitrogen management in the region.

As the lead agency for the SANH Project in the Maldives, MNU is committed to providing technical support for National level planning and to streamlining and institutionalise Nitrogen assessments so that scientific evidence could be used to determine policy action.

This Report - The Maldives Nitrogen Policy Report (MNPR) is a crucial first step in providing a snapshot of the status of Nitrogen emission in the Maldives, in-terms of Nitrogen sources, policy status, issues, challenges, and the way forward. The report explored the Nitrogen emission scenario and sheds light on the gaps and opportunities for Nitrogen management and identified the areas of greatest need for action.

The MNPR prescribes six priority sectors to be addressed. These are 1) transport, 2) energy, 3) waste, 4) waste management, 5) water management, and 6) agriculture. The MNPR also outlines the role of each of these sectors and the course for implementing various environmental policies toward the achievement of the objectives outlined in the MNPR.

Analysis of the Policy reviews summarised in the report shows hopeful results. An enabling environment exists for the key sectors as the policies focus on carbon and greenhouse gas emission reduction. Going forward, it would be essential to specify Nitrogen emission reduction targets in policy instruments and sector plans and to ensure the effective implementation of these plans in this endeavour for a safer, healthier planet.

Dr. Aishath Shehenaz Adam

Deputy Vice-Chancellor

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Abbreviations and Acronyms

ADB - Asian Development Bank

AGRONAT - Agro National Corporation Pvt Ltd.

BOD - Biological Oxygen Demand

C&C - Command and control

CCA - Climate and Clean Air Coalition

CO_2 - Carbon dioxide

ECOLEX database – Ecolex is an information service on environmental law, operated jointly by FAO, IUCN and UNEP

EDGAR - Emissions Database for Global Atmospheric Research (EDGAR), provided by the European Commission, Joint Research Centre (JRC)/Netherlands Environmental Assessment Agency (PBL)

EEZ - Exclusive Economic Zone

EIA - Environmental Impact Assessment

EPA - Environmental Protection Agency

ESAMF - Social Assessment and Management Framework

EU - European Union

GCF - Global Financial Crisis

GCRF - Global Challenges Research Fund

GDP - Gross Domestic Product

GHG - greenhouse gas

GPNM - Global Partnership on Nutrient Management

HIES - Household Income and Expenditure Survey

IFAD - International Fund for Agriculture Development (IFAD),

INDC - Intended Nationally Determined Contribution

INI - International Nitrogen Initiative

INMS - International Nitrogen Management System

IUCN - International Union for Conservation of Nature

IVA - Information and voluntary action

JICA – Japan International Cooperation Agency

kg - Kilogram

LGA - Local Government Authority

ltr - Litre

MBR - Market-based regulation and governmental expenditure

MCHE - Maldives College of Higher Education

MCOH - Maldives Climate Observatory, HDh. Hanimaadhoo

MEE - Ministry of Environment and Energy

MMRI - Maldives Marine Resource Institute

MMS - Maldives Meteorological Services

MNU - The Maldives National University

MoECCT - Ministry of Environment, Climate Change and Technology

MoFA - Ministry of Fisheries, Marine Resources and Agriculture

MoH - Ministry of Health

MW - Megawatt

MWSC - Male' Water & Sewerage Company Pvt. Ltd.

N, P, K - Nitrogen (N) Phosphorous (P) Potassium (K)

N_2O - Nitrous oxide

NA – Not applicable

NBS - National Bureau of Statistics

NDC - National Determined Contributions

NDMA - National Disaster Management Authority

NGO – Non-Governmental Organisation

NH_3 - Ammonia

NH_4 - Ammonium

NO_2 - Nitrites

NO_3 - Nitrates

NO_x - Nitrogen oxides

NPS – non point source

N_r - Reactive Nitrogen

NUE - nitrogen use efficiency

PM – Particulate matter

PSIP - Public Sector Infrastructure Projects

R&D - Research and development

RPF - Resettlement Policy Framework

SA – South Asia

SAARC - South Asian Association for Regional Cooperation

SACEP - South Asian Regional Cooperative Environmental Programme

SANC - South Asian Nitrogen Centre

SANH - South Asia Nitrogen Hub

SAP - Strategic Action Plan

SME – Small and medium-sized enterprises

SO_2 - Sulphur dioxide

STELCO - State Electric Company Ltd

STO - State Trading Organization

UKAID - UK Aid

UKCEH - UK Centre for Ecology and Hydrology

UKRI - UK Research and Innovation

UN SDGs - United Nations Sustainable Development Goals

UNDP - United Nations Development Program

UNEA - United Nations Environment Assembly

UNEP - United Nations Environment Program

UNFCCC - United Nations Framework Convention on Climate Change

UNFCCC - United Nations Framework Convention on Climate Change

UNICEF - United Nations Children's Fund

URA - Utility Regulatory Authority

USAID - United States Agency for International Development

WAMCO - Waste Management Cooperation

WHO - World Health Organisation

Executive Summary

The comprehensive study conducted in this report provides a necessary step to understanding the current nitrogen policy landscape for Maldives within South Asia. The report highlights the issues and challenges around nitrogen pollution and management, overview of the nitrogen issues at the global and national scale, methods and results from the SANH nitrogen policy dataset[1], the drivers of emissions and policy trends at the country level, emerging issues, and contains a case study overview of significant nitrogen control policies.

Being the first of its kind, this report provides a unique assessment of 40 national nitrogen related policies, valid for the Maldives in 2019. The policies are available in an open access database: Nitrogen-relevant policies from South Asia collected by South Asian Nitrogen Hub (SANH) 2020-2021, contains a total of 966 policies. The 40 policies of Maldives include direct relevant policies and indirect policies (that may not consider nitrogen in their formulation but have potential implications for nitrogen management). Maldives nitrogen-related policies contributed to 4% to the overall policies collected for South Asia.

The report has three key sections. Firstly, the background of the study presented in this report is outlined followed by the country profile and priorities. Secondly, an overview of the current nitrogen emissions and trends, drivers and impacts for the Maldives, within the context of South Asia is presented. Thirdly, a summary of the collection and analysis of 40 nitrogen related policies from Maldives is presented. Assessing nitrogen-related policies is crucial to identify the opportunities and gaps for managing nitrogen. The analysis of the policies provides fundamental information about the policies currently in place and to determine the action that is required in terms of policy review and action. The report is concluded with a brief overview of key stakeholders and recommendations for policy makers and the Maldivian community and the future outlook.

This report was developed by the Maldives National University and the UKRI GCRF South Asian Nitrogen Hub to contribute towards building a nitrogen policy arena for South Asia. The aspiration of the HUB is to support the Maldives Government and other stakeholders move forward with developing effective nitrogen policy actions that could be implemented nationally and locally.

[1] Yang, A. L. 2021. Nitrogen-relevant policies from South Asia collected by the South Asian Nitrogen Hub (SANH) 2020–2021. NERC EDS Environmental Information Data Centre.

BACKGROUND

- This report provides an assessment of nitrogen emission trends, drivers, and 40 nitrogen related policies in Maldives, valid in 2019.
- Nitrogen is essential for life, but nitrogen in its reactive form (N_r) in excess can cause severe harm to people and the environment. Excess reactive nitrogen (N_r) is a significant issue globally and for South Asia.
- Multiple sectors including agriculture, transportation, industry, and energy sectors have increased their share of nitrogen pollution and related greenhouse gas (GHG) emissions due to growing anthropogenic demands.
- Five principal threats of nitrogen pollution are to water quality, air quality, greenhouse-gas balance, soil quality, ecosystems and biodiversity.
- Addressing climate change by reducing greenhouse gas (GHG) emissions is a key priority in international politics. Managing nitrogen is essential for international climate change mitigation with nitrous oxide (N_2O), 300 times more warming potential than CO_2.
- South Asia is a global hotspot for N_r emissions for the main nitrogen compounds: nitrogen oxide (NO_x) nitrous oxide (N_2O), and ammonia (NH_3), with emission levels above global averages.
- Nitrogen pollution can be managed directly or indirectly by legislation, financial or regulatory measures taken by governments.
- Government and non-government measures can support and encourage efficient nitrogen management, and hence, minimize the negative impacts.
- The management of nitrogen is a major issue of international policy, yet information about nitrogen policies at the national level is scarce. There is a limited understanding of the policies, the issues addressed, and the types of instruments used, and how existing policies might impact nitrogen pollution. Addressing this knowledge gap is a key aim of this report.

UKRI GCRF SOUTH ASIA NITROGEN HUB (SANH)

- SANH aims to aims to tackle the nitrogen challenge by bringing together experts from leading research organizations from across South Asia and the UK. The hub focuses on four main areas: i) building the nitrogen policy arena for South Asia; ii) finding nitrogen solutions; iii) improving understanding and awareness of key nitrogen threats; iv) integrating regional nitrogen flows and impacts in south Asia.
- The South Asia Co-operative Environment Programme (SACEP) and SANH undertook an initial South Asian regional assessment of nitrogen emissions and policy and created a database of 966 nitrogen-relevant policies from South Asia.
- Drawing on that database, this SANH national report outlines the implications of these findings for Maldives. The country report is the first of its kind to provide a national overview on the extent of nitrogen-related policies for Maldives.

NITROGEN-RELATED POLICY ANALYSIS FOR MALDIVES

- For Maldives, 40 directly and indirect nitrogen–related policies, were collected, contributing to 4% of the SANH South Asia policy database.

- All nitrogen-related policies collected were classified based on certain characteristics. Classifications include: environmental sink[2]; sector; sub-sector; policy type; pollution source type; impact direction; relevance; and impact scope.
- The policy type classification indicates the type of policy instruments that are incorporated within a particular policy. A single policy may have multiple policy type characteristics, which indicate a more comprehensive approach. For Maldives, there were 66 classifications from the 40 policies, 19 policies (48%) of which had more than one policy type identification.
- The most common classification of policies was for multiple sectors at 35%. This is an advantageous policy characteristic indicating an understanding that multiple sectors have roles to play in N_r management.
- For environmental sinks, the most common classification was for multiple sinks at 43%. Multiple sink related policies are considered favourable since they consider multiple environmental areas and are better placed for N_r management
- Policies classified as having low relevance and/or low impact scope were omitted (11 policies, 28%), leaving 29 policies for further assessment and assumed to have a greater impact on how N_r enters the environment. Those policies identified to have a lower relevance and/or impact scope were not considered as irrelevant as amendments could be made to better adapt the policies to mitigate N_r waste.
- More than half the policies (63%) were identified as having a potentially positive impact on N_r management, as mostly environmentally orientated policies. Policies classified as mixed/neutral (38%), indicate to varying degrees dual goals for economic development and the environment. There were no policies identified with a negative impact direction including those that risk promoting N_r waste.
- Policies that address multiple sinks and/or sectors (with integrated objectives), identify pollution sources, and contain multiple policy types are well placed to confront the multidimensional challenges of nitrogen management.

DRIVERS OF REACTIVE NITROGEN EMISSIONS

- Emissions from all three nitrogen compounds, ammonia, (NH_3), nitrogen oxides (NO_x), and nitrous oxide (N_2O), have been increasing over time in south Asia and Maldives. These results highlight that current policy efforts so far have not yet been able to stabilise 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.
- Nitrous oxides (N_2O) have the steepest rise in Maldives by +171% since 2000 to 2015.
- There was a +169% increase in nitrogen oxides (NO_x) between 2000 and 2015. NO_x emissions are the highest (in total amount) compared to the other Nr compounds.
- For ammonia (NH_3), the emission levels in Maldives have been increasing steadily by +52% between 2000 and 2015. Ammonia emissions were from a range of sources including buildings (30%), electricity and heat (21%), solid fuels (17%) road transport (11%) etc.
- In 2015, the emission levels were NH_3 (63 tonnes), NO_x (9,974 tonnes) and N_2O (157 tonnes).
- One of the main sector sources of NO_x, as found for South Asia, includes the transport sector. Transport is also one the main contributing sources for nitrogen Oxide (NO_x) and ammonia (NH_3) emissions in the Maldives.
- Agriculture is not the main source of N_r emissions (NH_3 and N_2O) in the Maldives, in contrast to the regional South Asia findings.

[2] Sinks reflect the environmental aspect at risk (under threat) from N_r

- Indirect nitrous oxide (N_2O) emissions from atmospheric deposition of nitrogen in NO_x and NH_3 was the main source of N_2O at 57%, followed by "waste water treatment and discharge" (16%), road transport (11%) and other sectors (9%) as the biggest contributors.
- Energy contributes to 40% of NO_x emissions and 21% of ammonia (NH_3) emissions in 2015 in the Maldives. Electricity generation is one of the main sources of greenhouse gas (GHG) emissions for Maldives. Maldives achieved universal access to electricity in 2008, yet, national energy needs are almost solely reliant on fossil fuels. The main source of energy is oil, and only 4% is sourced from renewables.
- In Maldives, the industrial sector is expected to expand significantly in the coming years and is already emerging as a significant source of air and water pollution. As per the data of 2015, manufacturing and construction industries contribute 32% to nitrogen oxide (NO_x) emissions.
- The Buildings sector is one of the main contributors to all three N_r compounds. The sector contributed to both ammonia (NH_3) emissions (35%), with emissions increasing by +30% between 2000 and 2015. This sector contributed 25% to overall nitrogen oxide (NO_x) emissions and 12% to nitrous oxide (N_2O) emissions in 2018.

NEEDED ACTIONS

- In Maldives, 29 policies were related to nitrogen, but only a few of these specifically referenced nitrogen. As well as addressing nitrogen management systematically, such policies should also be accompanied by direct actions, such as 'core' policies, that contain regulatory and economic policy instruments. Setting quantifiable and enforceable constraints on N production and consumption in nitrogen-related policy is recommended.
- Existing policies can also be adapted to directly/ effectively address nitrogen management by referring explicitly to nitrogen pollution and relevant Nr compounds
- Policies need to specifically indicate N_r specific pollution source types and the risk of nitrogen waste in order to address nitrogen management. Only a small number (5% from a total of 29) of directly relevant policies were identified that fits this category.
- Sector based policies need to be directly linked with other policies to mitigate negative N_r impacts referring to one or more environmental sink. A large proportion (43%) of nitrogen relevant sector-based policies in Maldives have not referenced any sinks.
- To deal with N_r pollution better, it is necessary to have policies that address multiple sectors and sinks and policy instruments. Currently, two policies meet this criterion to some degree. Although not all policies would need to be integrated in this manner, a policy gap is visible.
- Tourism is one of the main contributors to the gross domestic product (GDP) of the country and also a core contributor to national N_r emissions through sectors such as transport. Lack of an overarching transport policy is considered a major gap in mitigating N_r emission.
- Action is needed in emerging sectors, considering relative changes in N_r emissions. Policy instruments need to take into consideration and address N_r emissions from emerging sectors and identify mitigations measures.
- The development of National Action Plans is advised in the United Nations Environment Assembly (UNEA-5) new resolution on sustainable nitrogen management. Maldives has the ability to strengthen regional and international commitments such as support of UNEA-5.2 and preparing for UNEA-6 to manage nitrogen sustainably.
- Further in-depth research on N_r relevant policies are necessary, to assess, amongst other aspects, their impact. SANH will continue to analyse N-relevant policy and engage with SACEP member states to broker a better understanding.
- Science-based decision-making is crucial to move towards N_r sustainability and SANH is supporting this journey to create the scientific evidence of the sources and causes of emissions, and ways to mitigate their impact. SANH will improve the scientific and technical base and help strengthen the Maldives contributions to address N_r ionally, regionally and beyond.

1. Introduction

Human interventions that convert nitrogen to its reactive form (N_r) have been essential for sustaining the global population. Whilst nitrogen is essential for life, excess N_r can cause catastrophic harm to people and the environment. Agriculture, transportation, industry, and energy have all increased their nitrogen pollution and related greenhouse gas (GHG) emissions due to growing demands. A GHG such as nitrous oxide (N_2O) has 300 times more warming potential than carbon dioxide (CO_2) produced by industry and combustion towards global warming. Five principal threats of nitrogen pollution are to water quality, air quality, greenhouse-gas balance, ecosystems and biodiversity.

Climate change is an important issue in international politics. However, the management of nitrogen that impacts climate change is a major challenge due to the scarcity of national level policies on nitrogen as well as lack of awareness among the policy makers and communities on the threat of nitrogen for a healthier planet.

An initial global assessment attempted to address this knowledge gap by creating the world's first nitrogen pollution policy database. Kanter and colleagues[3] identified 2,726 policies across 186 countries derived from the ECOLEX database[4], aiming to identify the gaps and opportunities in N 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 challenge.

An initial regional assessment of nitrogen emissions and policy was undertaken by SACEP and SANH for South Asia and the results were published in 2022 in a policy report[5]. These regional results were further featured in a scientific journal article[6]. It was found that South Asia (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka) is a major global nitrogen emission hot spot, primarily for the main nitrogen compounds: nitrogen oxide, nitrous oxide, and ammonia, with emission levels above global averages. Consequently, how nitrogen is managed in South Asia has global implications.

This SANH national report outlines the country level implications of these findings for Maldives. The comprehensive study conducted in this report provides a necessary step to understanding the current nitrogen policy landscape for Maldives within South Asia. The report highlights the issues and challenges around nitrogen pollution and management, overview of the nitrogen issues at the global and national scale, methods and results from the SANH nitrogen policy dataset, the drivers of emissions and policy trends at the country level, emerging issues, and contains a case study overview of significant nitrogen control policies. It is specifically focused on the evaluation of current policies, progress and barriers for Maldives. National level reports of this kind are being prepared for other SACEP member countries.

[3] Kanter, D.R., Chodos, O., Nordland, O., Rutigliano, M. and Winiwarter, W., (2020). Gaps and opportunities in nitrogen pollution policies around the world. Nature Sustainability, 3(11), pp.956-963.

[4] Ecolex. (2019). The gateway to environmental law. ECOLEX. Retrieved November 26, 2022, from https://www.ecolex.org/

[5] SACEP & SANH (2022) South Asian Regional Cooperation on Sustainable Nitrogen Management, Nitrogen Pollution in South Asia: Scientific Evidence, Current Initiatives and Policy Landscape, SANH Policy Paper PP1, Colombo & Edinburgh.

[6] Yang, A.L., Raghuram, N., Adhya, T.K., Porter, S.D., Panda, A.N., Kaushik, H., Jayaweera, A., Nissanka, S.P., Anik, A.R., Shifa, S. and Sharna, S.C., et al. (2022). Policies to combat nitrogen pollution in South Asia: gaps and opportunities. Environmental Research Letters, 17(2), p.025007.

1.1 Lead institution and SANH

The Maldives National University (MNU) is the first University to be opened in the Maldives, inaugurated on the 15th of February 2011. Previously known as the Maldives College of Higher Education (MCHE) established in 1999, as part of a restructuring and rationalization of all government-run post-secondary education in Maldives. MNU has had a long history as an educational institution since its inception in 1973. MNU offers a range of degrees, diplomas, and certificates, on fields such as education, engineering, health science, tourism, and more recently environmental management and marine science offered by a number of faculties and centres.

The South Asian Nitrogen Hub (SANH) is a UKRI GCRF funded research partnership that brings together 32 leading research organizations 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. The SANH program in Maldives is led by MNU.

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.

1.2 Why focus on nitrogen pollution?

Utilizing nitrogen, in its reactive form (N_r), has been essential for human development. Nitrogen has been altered in order to produce chemicals, fertilizers, and other useful products [7]. Agriculture depends on nitrogen, with fertilizers, largely synthetic, making it possible to fulfil global food demands. Likewise transport and wider industry depends heavily on fossil fuels for energy meanwhile emitting N_r as a by-product. It has been estimated that global reactive nitrogen (N_r) production has more than doubled during the last century as a result of human activity [8].

[7] Sutton, M.A., Bleeker, A., Howard, C.M., Erisman, J.W., Abrol, Y.P., Bekunda, M., Datta, A., Davidson, E., De Vries, W., Oenema, O. and Zhang, F.S., with contributions from Ayyappan S., Bouwman A.F., Bustamante M., Fowler D., Galloway J.N., Gavito M.E., Garnier J., Greenwood S., Hellums D.T., Holland M., Hoysall C., Jaramillo V.J., Klimont Z., Ometto J.P., Pathak H., Plocq Fichelet V., Powlson D., Ramakrishna K., Roy A., Sanders K., Sharma C., Singh B., Singh U., Yan X.Y. and Zhang Y. (2013). Our nutrient world. The challenge to produce more food & energy with less pollution. Centre for Ecology & Hydrology.

[8] Sutton, M.A., Oenema, O., Erisman, J.W., Leip, A., van Grinsven, H. and Winiwarter, W., (2011). Too much of a good thing. Nature, 472(7342), pp.159-161.

Human interventions, and increasing use of N_r, have led to nitrogen pollution. Nitrogen pollution can be defined as nitrogen containing compounds 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^+)[9]. The growing demands of sectors such as agriculture, transport, industry and energy have given rise to sharp increases in the levels of nitrogen pollution and related greenhouse gas (GHG) emission (UN, 2019). Five principal threats of nitrogen pollution are to water quality, air quality, greenhouse gas balance, ecosystems and biodiversity (see Fig 1) [9].

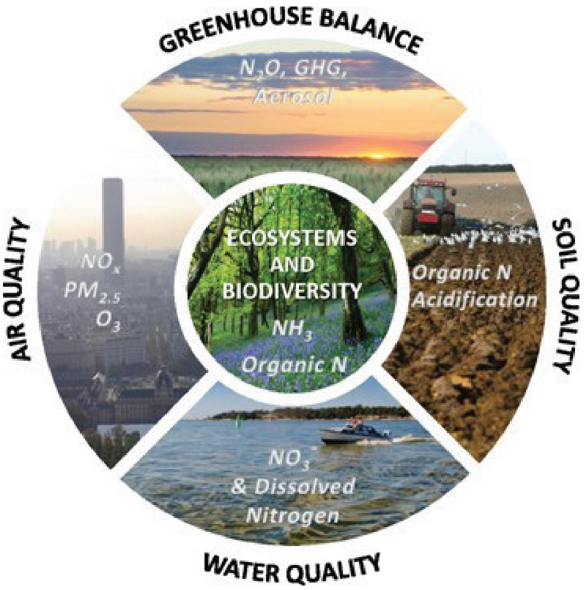


Figure 1: Threats from nitrogen pollution

Source: Sutton et al., 2013 [9]

Reductions in greenhouse gas (GHG) emissions are key to combating climate change, and a key area in international politics. The Paris agreement, in 2015, is a legally binding international commitment to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels [10]. Nitrogen management is essential for international climate change mitigation actions. It is known that nitrous oxide (N_2O) produced by industry and combustion, for example, is 300 times more warming potential than carbon dioxide (CO_2) as a GHG[11].

[9] Sutton, M.A., Bleeker, A., Howard, C.M., Erisman, J.W., Abrol, Y.P., Bekunda, M., Datta, A., Davidson, E., De Vries, W., Oenema, O. and Zhang, F.S., with contributions from Ayyappan S., Bouwman A.F., Bustamante M., Fowler D., Galloway J.N., Gavito M.E., Garnier J., Greenwood S., Hellums D.T., Holland M., Hoysall C., Jaramillo V.J., Klimont Z., Ometto J.P., Pathak H., Plocq Fichelet V., Powlson D., Ramakrishna K., Roy A., Sanders K., Sharma C., Singh B., Singh U., Yan X.Y. and Zhang Y. (2013). Our nutrient world. The challenge to produce more food & energy with less pollution. Centre for Ecology & Hydrology.

[10] UNEP. (2019). Frontiers 2018/19: Emerging Issues of Environmental Concern. Nairobi: United Nations Environment Programme.

[11] Robertson, G.P., Bruulsema, T.W., Gehl, R.J., Kanter, D., Mauzerall, D.L., Rotz, C.A. and Williams, C.O., (2013). Nitrogen–climate interactions in US agriculture. Biogeochemistry, 114(1), pp.41-70.

1.3 How does reactive nitrogen (N_r) impact the environment and 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[12]. Most of these costs were attributed to the impacts on human health.

Nitrogen global emission maps reveal south Asia as a hotspot (see Figures 2 and 4). Figure 2 illustrates the hotspots for nitrogen dioxide (NO_2) atmospheric pollution. Figure 3 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 to NO_x, and indirect exposure 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[13].

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. Particle size is directly related to their potential for causing health problems. Fine particles ($PM_{2.5}$) can cause the greatest health risk [14]. PM concentrations are argued to be higher in areas of growing populations undergoing fast urbanization and industrialization [15].

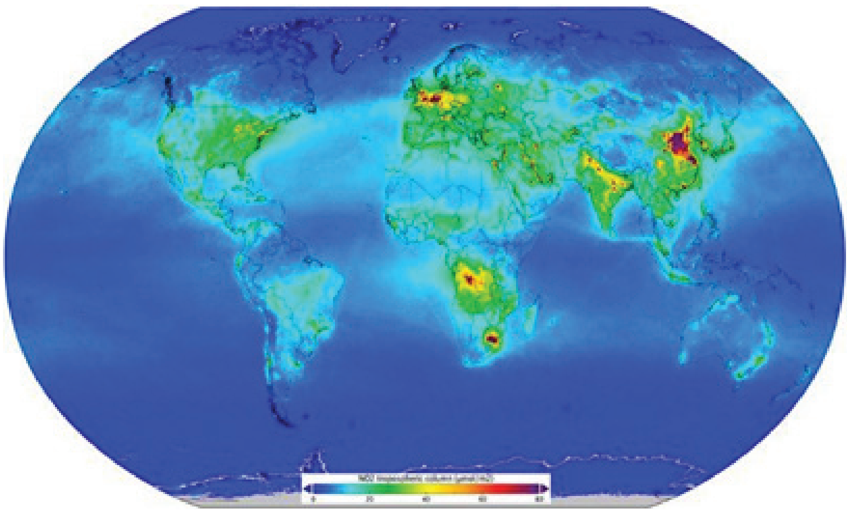


Figure 2: Global map of NO_2 (nitrogen dioxide) atmospheric pollution

Source: European Space Agency (2019) Note: Low levels of pollution are dark blue running to dark red for highest levels[16].

[12] Brink C., van Grinsven, H., Jacobsen, B.H., Rabl, A., Gren, I.M., Holland, M., Klimont, Z., Hicks, K., Brouwer, R., Dickens, R., Willems, J., Termansen, M., Velthof, G., Alkemade, R., van Oorschot, M., Webb, J. (2011). Costs and benefits of nitrogen in the environment (chapter 22) In: European Nitrogen Assessment (ENA): Sources, Effects and Policy Perspectives, edited by Sutton M. et al. Cambridge University Press

[13] Kegl, B., (2007). NO x and particulate matter (PM) emissions reduction potential by biodiesel usage. Energy & fuels, 21(6), pp.3310-3316.

[14] United States Environmental Protection Agency, (2022). Particulate Matter (PM) Basics https://www.epa.gov/pm-pollution (Accessed 16/10/22)

[15] Liu, X., Zou, B., Feng, H., Liu, N. and Zhang, H., (2020). Anthropogenic factors of PM2. 5 distributions in China's major urban agglomerations: A spatial-temporal analysis. Journal of Cleaner Production, 264, p.121709.

[16] European Space Agency. (2019). Copernicus Open Access Hub. Available online: https://scihub.copernicus.eu/

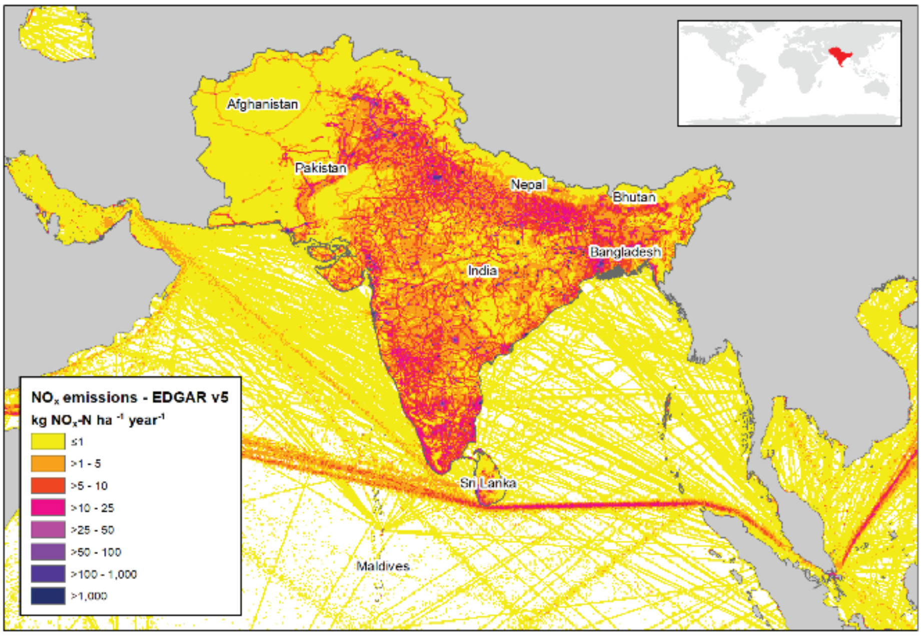


Figure 3: NO_x (nitrogen oxide) emissions across South Asia, 2015

Source: SACEP-SANH (2022)

The darker purple to blue colours indicate high concentrations of NO_x per hectare per year[17].

N_r can enter surface water and groundwater as a consequence of agricultural activity and the excess application of synthetic fertilizers and manures[18]. In addition, wastewater treatment, diffuse pollution, discharges from industrial processes, and motor vehicles also contribute to N_r found in water systems. Exposure to nitrates in drinking water can be particularly harmful to infants.

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 groundwater pollution[19]. Agricultural activities reportedly account for approximately 80% – 90% of the overall anthropogenic ammonia emissions[20].

17 SACEP & SANH. (2022). South Asian Regional Cooperation on Sustainable Nitrogen Management, Nitrogen Pollution in South Asia: Scientific Evidence, Current Initiatives and Policy Landscape, SANH Policy Paper PP1, Colombo & Edinburgh

18 WHO. (2011). Nitrate and Nitrite in Drinking-water: Background document for development of WHO Guidelines for Drinking-water Quality. Geneva: World Health Organization.

19 Sutton, M.A., Bleeker, A., Howard, C.M., Erisman, J.W., Abrol, Y.P., Bekunda, M., Datta, A., Davidson, E., De Vries, W., Oenema, O. and Zhang, F.S., with contributions from Ayyappan S., Bouwman A.F., Bustamante M., Fowler D., Galloway J.N., Gavito M.E., Garnier J., Greenwood S., Hellums D.T., Holland M., Hoysall C., Jaramillo V.J., Klimont Z., Ometto J.P., Pathak H., Plocq Fichelet V., Powlson D., Ramakrishna K., Roy A., Sanders K., Sharma C., Singh B., Singh U., Yan X.Y. and Zhang Y. (2013). Our nutrient world. The challenge to produce more food & energy with less pollution. Centre for Ecology & Hydrology.

20 Van Damme, M., Clarisse, L., Heald, C.L., Hurtmans, D., Ngadi, Y., Clerbaux, C., Dolman, A.J., Erisman, J.W. and Coheur, P.F., (2014). Global distributions, time series and error characterization of atmospheric ammonia (NH 3) from IASI satellite observations. Atmospheric chemistry and physics, 14(6), pp.2905-2922.

Ammonia is considered to be more harmful to ecosystems than nitrogen oxides (NO_x) especially when deposited in its dry form[21]. South Asia is a global hotspot for Ammonia emissions, indicated in Figure 3. The extent of ammonia emissions in South Asia are illustrated in further detail in Figure 4.

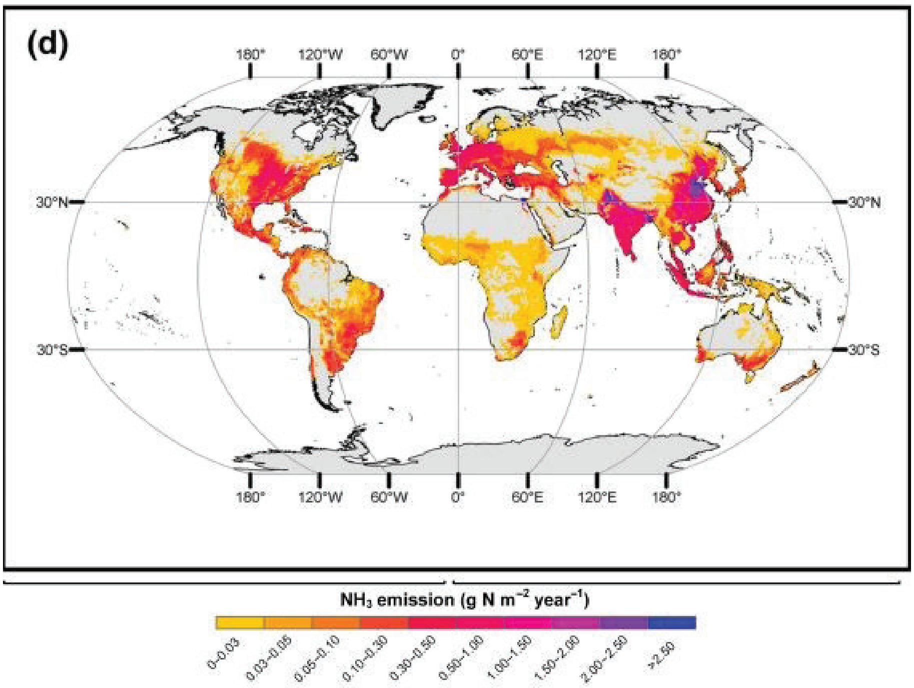


Figure 4: Global map of NH_3^- *(ammonia) emissions*

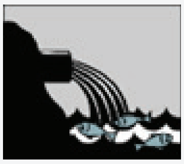
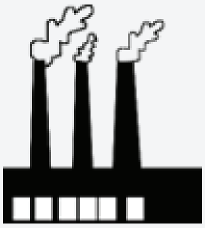
Source: Xu et al (2019) Note: this map is based off simulated ammonia emissions in response to application of synthetic nitrogen (N) fertilizer in the 2000s. Spatial resolution of 0.5 by 0.5 degree [22]*.*

[21] Hicks, W.K., Whitfield, C.P., Bealey, W.J. and Sutton, M.A. (2011). Nitrogen Deposition and Natura 2000: Science and Practice in Determining Environmental Impacts. COST office – European Cooperation in Science and Technology

[22] Xu, R., Tian, H., Pan, S., Prior, S.A., Feng, Y., Batchelor, W.D., Chen, J. and Yang, J. (2019). Global ammonia emissions from synthetic nitrogen fertilizer applications in agricultural systems: Empirical and process-based estimates and uncertainty. Global Change Biology, 25 (1):314-326.

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
Nitrate (NO_3) 	Wastewater, agriculture and oxidation of NO_x.	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) 	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) 	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). - modest odour contribution
Nitrous oxide (N_2O) 	Agriculture, industry, and combustion.	Used in rocket propel-lants and in medical procedures as laughing gas.	Health impact due to global warming, often enhanced by eutrophication health impact due to loss of stratospheric ozone depletion. 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

Provisioning, regulating, and supporting cultural ecosystem services[23] can be directly and indirectly affected by N_r[23]. 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, killing fish stocks, as visible in Figure 5, below.

Figure 5: Eutrophication zone in L. Dhanbidhoo

Yet, understanding nitrogen and its interactions with the environment is complex due to the large spatial and temporal variability; this is made even more complicated *'through the cascade of nitrogen through the environment and related linked effects'*[24].

Whilst local sources of nitrogen pollution, such as air emissions and run off, contribute to local effects, they also can contribute to accumulations at sub-national to global scales[24]. Nitrogen pollution does not respect country boundaries. Therefore, tackling nitrogen pollution requires trans-national cooperation.

SANH work across the eight south Asian countries to reinforce and support effective nitrogen management through a coordinated and integrated approach in the region. Collaborative efforts to tackle nitrogen are already underway. In 2019, spearheaded by Sri Lanka with the support of the UNEP, the "Colombo Declaration on Sustainable Nitrogen Management"' was adopted. It outlines an ambition to 'halve nitrogen waste by 2030'. United Nations member states have endorsed a proposed roadmap for action addressing nitrogen challenges.

[23] Ecosystem services are defined as the ecological and socio-economic value of goods and services provided by natural and semi-natural ecosystems, Erisman et al. 2014

[24] Erisman, J.W., Galloway, J.N., Seitzinger, S., Bleeker, A., Dise, N.B., Petrescu, A.R., Leach, A.M. and de Vries, W. (2013). Consequences of human modification of the global nitrogen cycle. Philosophical Transactions of the Royal Society B: Biological Sciences, 368(1621): 20130116.

1.4 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 incentivize the management of nitrogen more effectively, minimizing 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)[25]:

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[26] 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 measure for reducing nitrogen pollution requires 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 [27, 28].

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). Highlighting 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."

By 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 focused on minimising damaging emissions of nitrogen whilst maximising the benefits gained (European Commission, 2013).

Improvements to NUE require changes to agricultural practices. Scientists argue that sustainable agriculture practices, especially those closer to the natural systems as 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 (Jarvis et al., 2011; 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.

[25] Dalgaard, T., Hansen, B., Hasler, B., Hertel, O., Hutchings, N.J., Jacobsen, B.H., Jensen, L.S., Kronvang, B., Olesen, J.E., Schjørring, J.K. and Kristensen, I.S., (2014). Policies for agricultural nitrogen management—trends, challenges and prospects for improved efficiency in Denmark. Environmental Research Letters, 9(11), p.115002.

[26] Carter, N. (2007). The Politics of the Environment. Ideas, Activism, Policies 2nd edn (Cambridge: Cambridge University Press) 410

[27] Connor, D.J., Loomis, R.S. and Cassman, K.G., (2011). Crop ecology: productivity and management in agricultural systems. Cambridge University Press

[28] FAO. (2017). The future of food and agriculture–Trends and challenges. Annual Report.

Focusing measures at one scale can also be limited. A study identified that the majority of policies aiming to reduce N pollution in agriculture targeted one scale, i.e., farm level[29]. However, such policies on their own are argued to be inadequate as N_r loss also happens beyond the farm. There are opportunities for intervention along the value chain; from fertilizer manufacturers, transportation, retailers, consumption and wastewater treatment [29]. 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 [30].

Nitrogen pollution is not just an issue for agriculture. Addressing other sectors such as energy, waste, industry, transport, urbanisation, tourism, and more, are also vital for addressing the global N challenge. For example: tackling emissions of air pollutants from transport. 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[31]. Localized measures may include low-emission zones in cities and congestion charges.

Figure 6 gives some examples of other measures that can promote clean air practices to reduce PM pollution. These are 25 'most effective' measures listed by the Climate and Clean Air Coalition (CCAC). 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 $PM_{2.5}$.

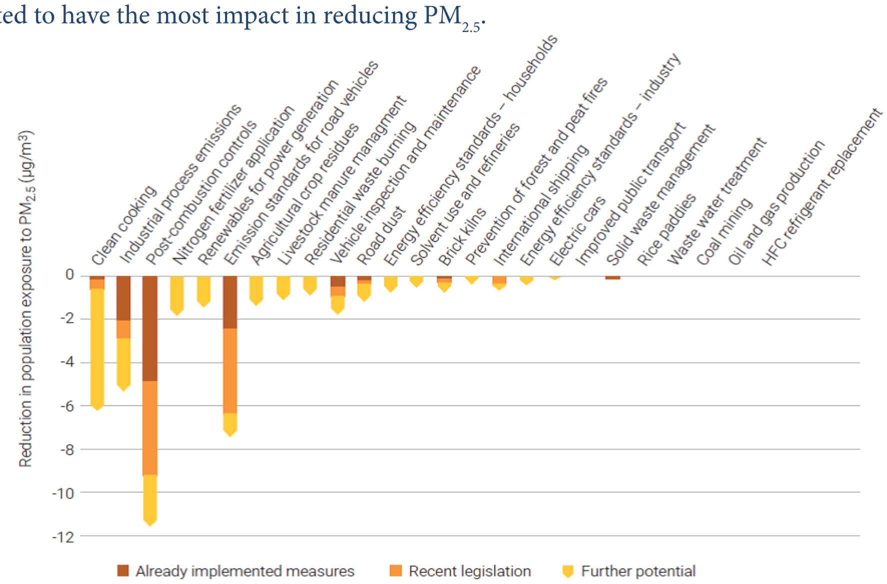


Figure 6: Impacts on population-weighted exposure to $PM_{2.5}$ in 2030 from implementation of 25 clean air measures, ranked by further potential

Source: Climate and Clean Air Coalition 2019, UNEP 2019

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[30] 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 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[32].

[29] Kanter, D.R., Bartolini, F., Kugelberg, S., Leip, A., Oenema, O. and Uwizeye, A., (2020). Nitrogen pollution policy beyond the farm. Nature Food, 1(1), pp.27-32.

[30] UNEP (2019). Frontiers 2018/19: Emerging Issues of Environmental Concern. Nairobi: United Nations Environment Programme.

[31] European Environment Agency (EEA), (2020). Indicator assessment; Emissions of air pollutants from transport, https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-air-pollutants-8/transport-emissions-of-air-pollutants-8

[32] Gunningham, N., & Grabosky, P., (1998). Smart regulation. Designing environmental policy. New York: Oxford University Press.

1.5 Global and South Asia policy events

The UNEP report[33] 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 (See, Appendix, Figure 24). The International Nitrogen Institute (INI), established in 2003, is a key initiative that helped catalyse following 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 [34]. In 2012, the South Asian Nitrogen Centre (SANC) was established as one of the six INI centres in the world.

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 organizations to respond to the 'nutrient challenge'. The GPNM currently chaired by India, is under 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, on October 2019. With the declaration comes the ambition to 'halve nitrogen waste by 2030' whilst highlighting the multiple benefits across all the UN SDGs.

Prior to these events 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 another key mechanism for regional intergovernmental collaborations to tackle nitrogen waste.

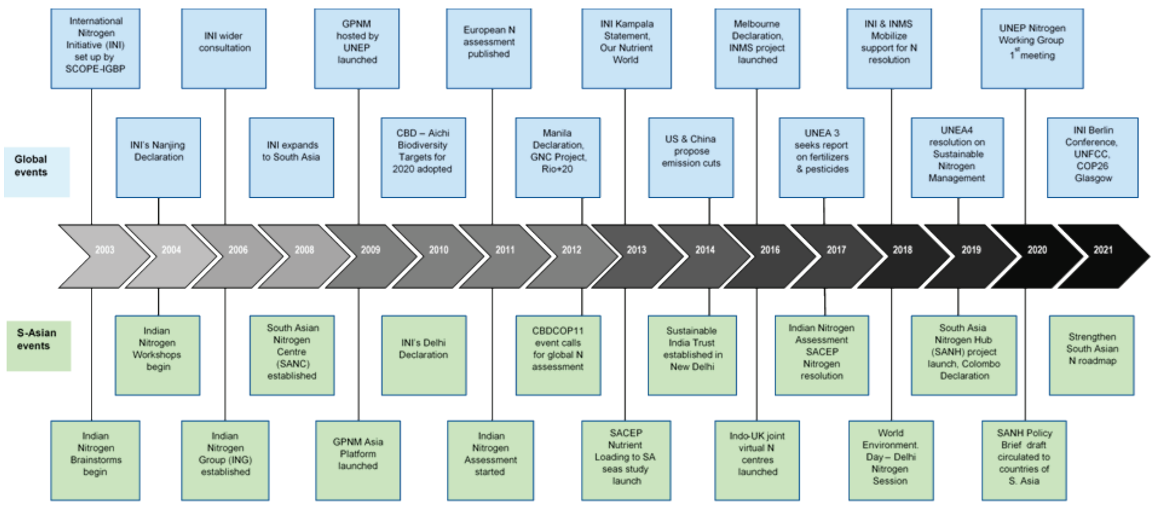


Figure 7: Timeline of global and South Asian developments toward global cooperation on sustainable nitrogen management

Source: Raghuram et al. (2021) [34]

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[33] UNEP, (2019). Frontiers 2018/19: Emerging Issues of Environmental Concern. Nairobi: United Nations Environment Programme

[34] Raghuram, N., Sutton, M.A., Jeffery, R., Ramachandran, R. and Adhya, T.K. (2021). From South Asia to the world: embracing the challenge of global sustainable nitrogen management, One Earth, 4 (1):22-27. https://doi.org/10.1016/j.oneear.2020.12.017

1.6 What do we know about nitrogen policies?

Nitrogen management is a major international policy issue and international policy actions are easier to track. So far, very little is known about the nitrogen policy landscape at national levels. There is a limited understanding on the number of current nitrogen-related policies, the issues addressed, and the types of instruments being used. In addition, how existing policies may inadvertently lead to increases in nitrogen pollution is also poorly understood.

An initial international assessment attempted to address this knowledge gap by creating the world's first nitrogen pollution policy database. Kanter and colleagues[35] identified 2,726 policies across 186 countries derived from the ECOLEX database, aiming to identify the gaps and opportunities in N policy, around the world. In overall, their analysis revealed that policy integration was limited and ill-equipped to deal with the cross-cutting nature of the global N challenge. Furthermore, policy fragmentation, and the lack of understanding on nitrogen-related policies and their trade-offs are barriers against tackling the nitrogen challenge. The regional and country level implications of the N policy database are yet to be examined for South Asia, which is a key aim of SANH project Work Package 1.1.

This report is a first of its kind to provide a national overview on the extent of nitrogen-related policies for Maldives. Its analysis includes direct and indirect policies that may not consider nitrogen in their formulation but may have potential implications for nitrogen management. By building a better understanding of the current nitrogen policy landscape both at the national and region level, will support efforts to develop effective nitrogen management policies in the future and support progress for the road map for action under the sustainable nitrogen management commitments.

2. Country level profile and priorities

2.1 Biophysical characteristics

The Republic of Maldives is a nation of 26 coral atolls comprising of 1,192 small islands located in the Indian Ocean to the southwest of India and Sri Lanka. It is the smallest country in Asia by population and land area. The double chain of islands distributed in a north to south direction over the equator is around 820 km long and 80 to 120 km wide (see Figure 6). The country is divided into 20 administrative atolls and the capital is Male' (see Appendix Table 28). The islands are small and vary in size along the length of the country ranging from 0.5 to 5 km^2. The land formations are flat without hills or rivers but some islands have dunes that reach up to 2.4m above sea level[36]. Over 80% of the land area is less than 1m above sea level [37].

[35] Kanter, D.R., Chodos, O., Nordland, O., Rutigliano, M. and Winiwarter, W. (2020). Gaps and opportunities in nitrogen pollution policies around the world. Nature Sustainability, 3(11), pp.956-963.

[36] Embassy of the Maldives: Brussels. (2022). About Maldives: Geography & Location. Retrieved February 1, 2022, from https://www.maldivesembassy.be/en/about-maldives/geography-location

[37] MEE. (2016). State of the Environment., (2016). Ministry of Environment and Energy, Male', Maldives.

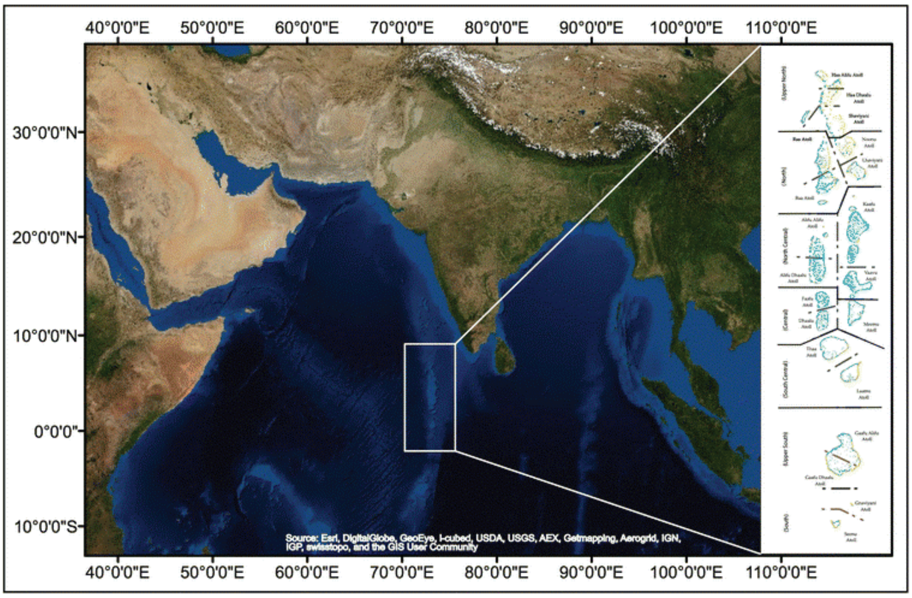

Figure 7: Geographical location of Maldives in the Indian Ocean, S.E. Asia. Zoomed out map to the right shows the map of the country (Source: Fallati et al., 2017)[38]

Out of the 1,192 islands, 1,074 are vegetated[39] and approximately 450 are un-vegetated[40] (see Table 2). The largest inhabited island is the island of Gan in Laamu Atoll at 6.13 km^2 and the largest uninhabited island is Gan in Seenu Atoll at 2.89 km^2 which has the international airport in the south of the country.

The population is widely dispersed over 187 islands, commonly known as "inhabited islands". Additionally, 164 islands are used as tourist resorts while 853 islands are uninhabited.

Table 2: Information on the islands of Maldives

Description	Total number	Source
Total number of islands	1192	(MEE, 2015)
Vegetated islands [39]	1074	
Un-vegetated islands [40]	450	
Islands used for human settlement	187	(National Bureau of Statistics, 2020)
Uninhabited islands	853	
Islands developed as tourist resorts (including Marinas)	164	

[38] Fallati, L., Savini, A., Sterlacchini, S. and Galli, P., (2017). Land use and land cover (LULC) of the Republic of the Maldives: first national map and LULC change analysis using remote-sensing data. Environmental monitoring and assessment, 189(8), pp.1-15.

[39] Vegetated islands comprise of both natural vegetated islands and artificial vegetated islands.

[40] Unvegetated islands include sand banks (Finolhu), natural coral conglomerates above high tide level (Huraa) and artificial un-vegetated islands.

2.2 Land cover and land use change

The Exclusive Economic Zone (EEZ) of the country covers an area of 859,000 km^2 (see Table 3). The total land area is 227 km^2 and it is documented that 90% of the islands are less than 0.5km^2 in area. This figure may have changed as a number of islands have new land added by land reclamation over the recent years[41]. It is estimated that 26% (79 km^2) of Maldives land area was used for agriculture in 2018 [42].

Table 3: Breakdown of land cover and land use for Maldives from different sources

Land Cover and Land Use	km^2	%	Source
Exclusive Economic Zone (EEZ)	859,000	-	(MEE, 2015)
Total country area (water and land)	115,300	99	
Total land area	227	1	
Water bodies (wetlands and mangroves)	8	3	
Agricultural land	79	26	(The World Bank, 2021) - data 2018

2.3 Soil

The soil in Maldivian islands is made up of substantial quantities of un-weathered coral parent material, coral rock and sand. The water holding capacity of soil is poor due to high porosity and high infiltration rates. The soils of Maldives are generally alkaline with pH values ranging from 8.0 to 8.8. The soils are generally poor and deficient in nitrogenous nutrients, potassium and several micronutrients particularly iron, manganese and zinc. Though the phosphorus content of the soils is high, it is present mostly in the form of calcium phosphate and, thus, remains unavailable to plants [43].

2.4 Vegetation

The country's vegetation and other ecological features vary from the north to south of the country. With uniform topography, soil and climate, the diversity of terrestrial flora is low in Maldives and yet, the islands support rich coastal vegetation[44]. The flora of the country consists of 583 vascular plants of which 323 are cultivated plant species and 260 are native and naturalized plants. From the 260 native or naturalized plant species, less than 100 are indigenous [45].

[41] BBC. (2020). A new island of hope rising from the Indian Ocean. Retrieved from https://www.bbc.com/travel/article/20200909-a-new-island-of-hope-rising-from-the-indian-ocean

[42] The World Bank. (2018). Agricultural land (% of land area) - South Asia | Data. Retrieved 24 October 2021, from https://data.worldbank.org/indicator/AG.LND.AGRI.ZS?locations=8S

[43] MEE, (2015). Fifth National Report of Maldives to the Convention on Biological Diversity. Maldives: Ministry of Environment and Energy

[44] FAO. (2016). Common Plants of Maldives. Retrieved 12 July 2021, from http://www.fao.org/3/i5777e/i5777e.pdf.

[45] Climate Risk Country Profile: Maldives (2021): The World Bank Group and the Asian Development Bank.

2.5 Mangrove forests

Maldives being an island nation, the country lacks watersheds and rivers in its natural setting and 75 islands contain small fresh-water lakes, either associated with swampy depressions or brackish water ponds with mangroves along the edges[46]. Mangroves are an inherent part of some islands and records show that 15 mangrove plant species out of the 17 species reported from atolls in the Indian Ocean are found in the Maldives. The mangrove ecosystems protect the islands from storm surges and swell waves, fight climate change through carbon sequestration and acts as a natural habitat for juvenile species [47]. The approximate total wetland or mangrove area is 8 km^2 making up to 3% of the land area (see Table 3).

2.6 Marine and Coastal environment

The islands of Maldives are dispersed over an area of 90,000 km^2 in the ocean. The ocean covers 99% of the country while land is just 1%. Maldives depend on the coastal and marine environment for its economy, livelihood, protection of the islands and food security. The Maldivian atolls form the seventh largest reef system in the world. The unique and rich diversity of coral reefs of Maldives makes them globally significant. The total reef area is 4,500 km^2 representing about 3.24% of global reef area[48]. The marine ecosystems of the Maldives have been recognized among the most diverse and richest in the world [49].

Due to the small size of the islands in the Maldives, the whole land area is considered as a coastal zone. Beaches represent approximately 5% of the total land area[50]. Beaches are particularly dynamic with seasonal changes. Additionally, human interventions including poor waste management practices, coastal modifications and unsustainable extraction of resources place further stress on the coastal areas of the islands. Beach erosion is one the most significant challenge faced by the communities in the Maldives, with over 80% islands facing erosion issues.

The Government of Maldives places high importance on protecting and conserving of the marine and coastal environment and several legislations have been developed and enacted in this regard (see appendix, Table 28). The Strategic Action Plan (SAP) of the Government (2019 – 2023) states that the economy and well-being of the Maldives is tied to the health and wealth of the natural environment; primarily the ocean. The SAP outlines policy priorities of the Government for the protection and conservation of the marine and coastal environment.

2.7 Water availability

The islands of the Maldives lack availability of surface freshwater; therefore, it is both temporally and spatially scarce across the country. The natural freshwater resources are the groundwater aquifers that occur in the porous coral sands and recharged through annual rainfall. Other freshwater resources include small fresh or brackish water ponds in few islands and rainwater collected in tanks.

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[46] Embassy of the Maldives: Brussels. (2021). About Maldives: Geography & Location. Retrieved 13 July 2021, from https://www.maldivesembassy.be/en/about-maldives/geography-location

[47] MUI By Six Senses Laamu. (2020). Mangrove forests. MUI By Six Senses Laamu. Retrieved February 10, 2022, from https://www.maldivesunderwaterinitiative.com/mangrove-forests#:~:text=Locally%20referred%20to%20as%20%E2%80%9CKhuli,%2C%20fish%2C%20sharks%20and%20rays

[48] MEE. (2016). State of the Environment 2016, Ministry of Environment and Energy, Male', Maldives.

[49] Kanvinde, H. (1999). Maldivian gender roles in bio-resource management. Bangkok: Food and Agricultural Organization of the United States

[50] Shaig, A. (2006). Climate change vulnerability and adaptation assessment of the land and beaches of Maldives-technical papers to Maldives national adaptation plan of action for climate change. Ministry of Environment, Energy and Water

Shallow depth of the groundwater lenses of the islands make the freshwater resource vulnerable and susceptible to contamination from natural causes and land-based human activities such as the use of septic tanks (for wastewater disposal), disposal of waste on land, excessive application of fertilizers, pesticides and fungicides for agricultural purposes[51, 52]. Fresh groundwater have also been depleted in many islands as a result of over-extraction of groundwater. Hence, people have ceased using groundwater for drinking or cooking as the quality has deteriorated. Most of the island communities rely on rooftop harvested rainwater for potable purposes (87% of the populations in the islands use rainwater as the main source for drinking)[53].

Climate change is posing challenges on water security in the country. Warming temperatures, changes in precipitation patterns, and sea level rise have affected and will likely continue to affect water supply and quality. Each year several islands report water shortages, and the Government provides supplies to cater to this need. Desalinated water is the source of water supplied to the islands, in 2015, a total of 2,909m^3 of desalinated water was transported on ships to 61 islands.

In an effort to provide a long-term solution to this problem the Government has developed water supply schemes to enhance rainwater harvesting capacity and to provide reverse osmosis plants with storage capacity in the islands. As a result, the population with access to water supply with metered house connection increased from 25% in 2013 to 75% in 2019[53].

2.8 Climate

Located on the equator, Maldives experiences a monsoonal climate with two distinct seasons known as the dry season (northeast monsoon) from January to March and wet season (southwest monsoon) that extends from May to November. The temperature hardly varies throughout the monsoon seasons as shown in Figure 8. The daily temperature ranges from approximately 31°C during the day to 23°C in the night.

The annual rainfall in Maldives is 1,890mm with the southern atolls receiving more rainfall compared to the northern and central regions. The entire country experiences heavy rain during the southwest monsoon (refer Figure 8). There is a considerable decrease in rainfall during the northeast monsoon and drought periods have been experienced specifically in the northern part of the country.

[51] MEE. (2017). State of the Environment 2016, Ministry of Environment and Energy

[52] National Bureau of Statistics. (2018). Review Report on Water and Waste Accounts. Malé': National Bureau of Statistics. Retrieved from http://statisticsmaldives.gov.mv/nbs/wp-content/uploads/2020/06/Water-and-Waste-Account-Review-Report-NBS.pdf

[53] MEE. (2017). National water and sewerage policy, Ministry of Environment and Energy, Male', Maldives.

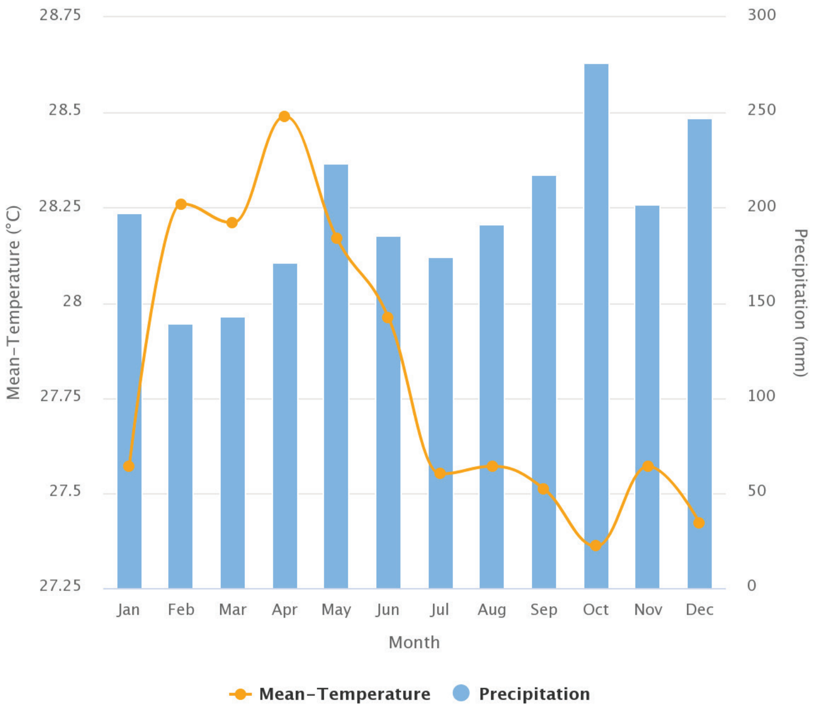


Figure 8: Climate overview of Maldives 1991 – 2020: Precipitation and Mean Temperature, Source: World Bank Group, 2021

2.9 Climate change

Characterized by a warm and humid tropical monsoon climate, and being a low-lying small island nation with more territorial sea than land, Maldives is extremely sensitive and vulnerable to the effects of climate change. The country's economy and communities are continuously affected by the changes in climatic conditions leading to sea level rise, storm surges and flooding. Over the past six years, 90 islands of Maldives have experienced flooding [54].

At present, the average temperature ranges from 27.95°C to 28.5°C while the projected average annual temperature, based on moderate GHG emissions scenario, suggests warmer days with temperatures between 29.05°C and 30.15°C[55]. Amongst the climatic changes recorded, one of the most pressing issues that the Government had to address is the periods of drought and water shortages that affects the northern and central atolls due to uneven rainfall distribution or limited seasonal precipitation. In addition, lack of other potable water sources also contributes to water insecurity for farmers as well as to the general public[56].

The Maldives government is firm in its commitment to combat climate change and stated that 'building the resilience and low emission development is a key priority of the country[57]. The government has launched several programs and projects in order to mitigate the effects of climate change, focusing on climate resilient developments, sustainable environmental management, Clean Energy and enhancing water security.

[54] Shaig, A., (2006). Climate change vulnerability and adaptation assessment of the Maldives land and beaches. Center for Disaster Studies, James Cook University, Australia.

[55] Center for Excellence in Disaster Management & Humanitarian Assistance, CFE-DM. (2021). Maldives Disaster Management Reference Handbook. Retrieved October 28, 2021, from: https://reliefweb.int/sites/reliefweb.int/files/resources/disaster-mgmt-ref-hdbk-Maldives2021.pdf

[56] MEE. (2017). State of the Environment 2016, Ministry of Environment and Energy.

[57] MEE. (2019). *Maldives First Biennial Update Report to the UNFCCC*, Ministry of Environment

3 Socio-economic context

3.1 Demography

The population of Maldives was 344,023 in 2014 and the annual growth rate was recorded at 1.65 which has been decreasing steadily from 1990 onwards. The population was estimated to be 533,941 in 2019 [58] and the capital city, Male' is home to more than 30% of the population[59].

3.2 Economy

Maldives economy has grown rapidly since 1975 as evident from improvements in socio-economic indicators and poverty reduction[60], for example, improvements in the quality and affordability of public services, progress in health and education indicators (with a literacy rate at 98%), and a life expectancy of over 78 years[61]. The development of tourism has been a key driver for economic development and poverty reduction. It is reported that the annual GDP growth averaged 6.3% from 2015 to 2019 (pre-pandemic), faster than other small island and upper middle-income economies[62]. Maldives was ranked second with a GDP growth rate of 7% in comparison to other South Asian countries (see Figure 9).

Traditionally, Maldives relied on the fisheries industry as the major contributor to the GDP until the tourism sector took over in 1978. Since then, the fisheries sector has steadily declined and records show that the contributions to the national GDP has declined from 22% in 1999 to 4% in 2016, whilst the tourism sector experienced rapid growth[63].

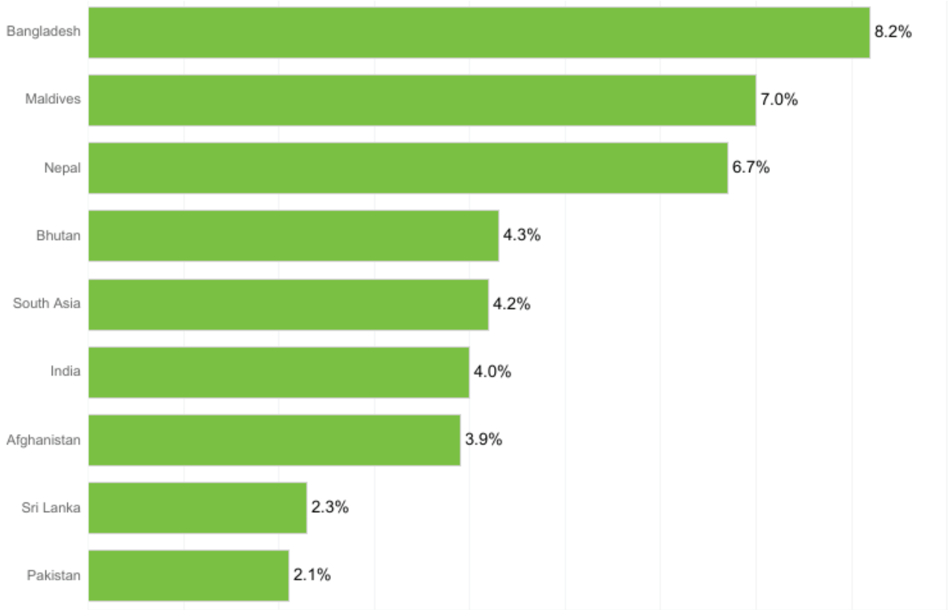


Figure 9: GDP Growth Rate, 2019 (Source: Asian Development Bank, 2021)

[58] National Bureau of Statistics. (2015). Statistical release I: Population and Households. Maldives Bureau of Statistics Statistical Release I Population and Households Comments. Retrieved February 2, 2022, from http://statisticsmaldives.gov.mv/population-and-households/

[59] The World Bank. (2022). The World Bank in Maldives: Overview. Retrieved 19 April 2022, from https://www.worldbank.org/en/country/maldives/overview#1

[60] FAO. (2011). Maldives and FAO achievements and Success Stories. Retrieved March 30, 2022, from https://www.fao.org/3/at010e/at010e.pdf

[61] World Bank. (2021). The World Bank In Maldives, retrieved on 30/03/2022 https://www.worldbank.org/en/country/maldives/overview#1

[62] IsDB. (2022). Member country partnership strategy for the Republic of Maldives (2022-2025); A RESILIENT AND SUSTAINABLE LIFE, AND DIVERSIFIED ECONOMY FOR MALDIVIANS. Retrieved March 30, 2022, from https://www.isdb.org/publications/member-country-partnership-strategy-for-the-republic-of-maldives-2022-2025

[63] MEE. (2019). Maldives First Biennial Update Report to the United Nations Framework Convention on Climate Change, Maldives: Ministry of Environment

Development and economic growth are categorized under primary (agriculture and fisheries), secondary (manufacturing, water, electricity and construction) and tertiary (wholesale and retail trade, tourism, transport and communications, financial services, real estate, professional and technical activities, public administration, education, human health and social work, entertainment, recreation and other) activities by the National Bureau of Statistics. For the year 2019, primary economic activities contributed to 4.1%, secondary 10.6% and tertiary 75.1% to the GDP (see Table 4).

Table 4: GDP Tables 1995 – 2020. (Source: National Bureau of Statistics, 2020)[64].

Economic Activities	% of GDP	
	2010	2019
Primary	6.4	4.1
Secondary	8.2	10.6
Tertiary	75.7	75.1

3.3 Food security

Food security in Maldives has distinctive features as the country depends on imports for most of its food needs, including rice, which is the staple grain. Fishing and subsistence agriculture are the main sources of food security and livelihoods for the communities in the outer islands. Lack of a robust supply chain, food storage limitations, geographic challenges in distribution and access to markets are some of the challenges that affect food security. In addition, climate change is adversely affecting agriculture and fish stocks and reducing cultivable land area due to effects such as tidal waves, flooding, and salt water inundation. Climate change may also exacerbate extreme weather events which may impact fish catch for the country and diminishing the primary source of dietary protein for the country[65].

In 2020 there was a shortage in food supply imports into the country due to the COVID-19 pandemic and it emphasised the vulnerability of the country to global shocks and volatilities in global commodities markets. The situation was managed with quick and strategic responses by the Government to resolve the issue including measures in controlling the prices of essential food products. However, the supply chain continued to be disrupted causing the volatility in food prices, and imports of food increased by 25% from January - May 2020[66].

Government emphasises diversification of green and blue livelihoods and economy, including agri-business, focusing on strengthening SMEs and inclusion of youth and women empowerment[67]. Food security will be enhanced by investing into commercial scale agriculture, with targeted policy interventions focusing on amendments to the import and export regime to facilitate growth and to attain sustainability[68]. Local productivity would be increased through contract farming and under the 'Import Substitution Programme' 17 crops have been identified to be produced on 44 islands. In addition, a levy of rent-free three years was given to islands designated for farming and lease payments were deferred for six months[69].

[64] National Bureau of Statistics, (2020), Annual Gross Domestic Product, Male', Maldives https://statisticsmaldives.gov.mv/gdp-production/

[65] FAO. (2018). Impacts of climate change on fisheries and aquaculture Synthesis of current knowledge, adaptation and mitigation options. Retrieved 22 May 2022, from https://www.fao.org/3/i9705en/i9705en.pdf

[66] United Nations, (2020) COVID-19 Socioeconomic Response And Recovery Framework, United Nations in Maldives https://unsdg.un.org/sites/default/files/2020-08/MDV_Socioeconomic-Response-Plan_2020.pdf

[67] Government of Maldives, (2019). Strategic Action Plan (2019-2023) https://presidency.gov.mv/SAP/

[68] Government of Maldives, (2019). National Resilience and Recovery Plan (2019-2023) https://presidency.gov.mv/Pages/Index/224

[69] Ministry of Economic Development and UNDP, 2020. Impact of the COVID-19 crisis in the Maldives rapid livelihood assessment, UNDP

4. Overview of Maldives reactive nitrogen (N_r) pollution trends

4.1 Nitrogen emission data overview

The nitrogen emission data analysed in this chapter is provided by the Emission Database for Global Atmospheric Research (EDGAR)[70] developed by the Joint Resource Centre (JRC). SANH selected EDGAR as the common data source for N_r emissions to enable comparability and consistency across our analyses of the eight South Asian countries.

The data in this section provides an overview into N_r emissions only. 'Emissions' refer to the production and discharge of substances into the air, especially pollutants as gas. Nonetheless, 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 emissions, which impact the air and climate, but also indirectly, due to nitrogen cascades, impacting other sinks[71].

4.2 Regional and National Reactive Nitrogen Emission trends of Key Compounds

The major three reactive nitrogen (N_r) compounds of global concern include the greenhouse gas (GHG) nitrous oxide (N_2O) and the two ambient air pollutants nitrogen oxides (NO_x) and ammonia (NH_3). South Asia is a global hotspot for all three nitrogen compounds, with emissions above that of global levels[72].

Nitrogen oxide (NO_x) emissions have been increasing rapidly across South Asia, and more than doubled since 2000. Electricity and heat generation is the main nitrogen oxide (NO_x) emission source, with 'road transport' and 'manufacturing and construction' also as major regional contributors. Ammonia (NH_3) and nitrous oxides (N_2O) have also been increasing steadily with agriculture as a major source through managed soil and fertilizer use.

For Maldives there are somewhat similar patterns in the N_r emissions trends to that of the South Asia region, but also some divergences. Figures 10 illustrate the trends since 1970 for all three major N_r compounds nitrous oxide (N_2O) and nitrogen oxides (NO_x) and ammonia (NH_3) and for particulate matter ($PM_{2.5}$ and PM_{10}).

[70] EDGAR Database: https://edgar.jrc.ec.europa.eu/ 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

[71] Galloway, J.N., Aber, J.D., Erisman, J.W., Seitzinger, S.P., Howarth, R.W., Cowling, E.B. and Cosby, B.J. (2003). The Nitrogen Cascade. Bioscience 53 (4):341-356

[72] SACEP & SANH. (2022). South Asian Regional Cooperation on Sustainable Nitrogen Management: Nitrogen Pollution in South Asia: Scientific Evidence, Current Initiatives and Policy Landscape, SANH Policy Paper PP1, Colombo & Edinburgh.

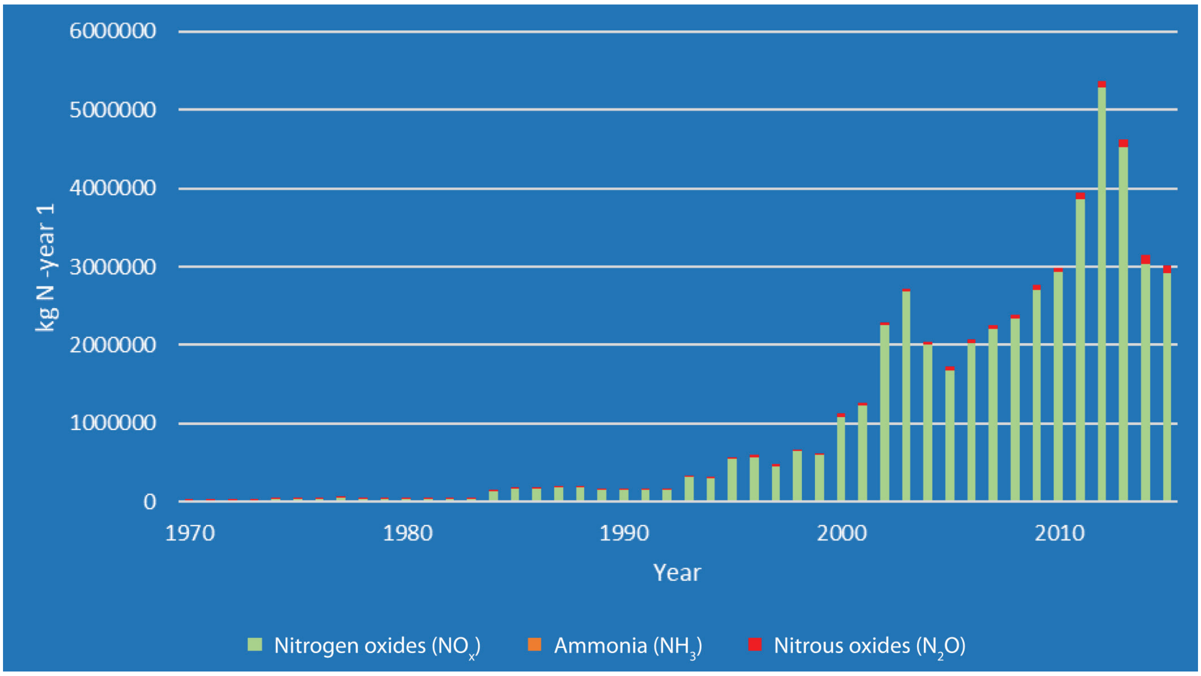


Figure 10: Maldives reactive nitrogen emission trends for nitrogen oxides (NO_x), Ammonia (NH_3), and nitrous oxides (N_2O) from 1970 to 2015. Note: Data is sourced from EDGAR v6.0 Greenhouse Gas Emissions data and Global Air Pollutant Emission data sourced from Crippa et al., (2019a; 2019b). The total N_r emissions (in tonnes) have been converted to N, kilogram (kg) per year. NH_3 is not visible due to its relative low amounts compared to N_2O and NO_x.

4.3 Nitrogen emission changes and the status

In Maldives the EDGAR data indicates that all three nitrogen compounds, ammonia (NH_3), nitrogen oxides (NO_x), and nitrous oxide (N_2O), have increased from 2000 onwards and peaked between 2012 and 2013 (see Figure 10). From then onwards there was a slight decrease in all three nitrogen compounds. Data that is more recently available (until 2018) indicated that N_2O emissions began to rise again after 2016.

N_r emission records from 2000 to 2015 indicate that nitrogen oxides (N_2O) have increased the most (171%) since 2000 to 2015, see Table 5 and Figure 10. Nitrogen oxide (NO_x) emissions had the second highest increase (169% between 2000 and 2015) and ammonia (NH_3) emissions increased by 52%. NO_x emissions were the highest in 2015 compared to the other compounds (at 9,576 tonnes). The total amounts of NO_x highlight that this compound should be a key priority for policy action for Maldives.

Table 5: National Changes in emissions of key reactive nitrogen compounds, 2000-2015 for Maldives Note: Data is sourced from EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a) and EDGAR v6.0 Greenhouse Gas Emissions sourced by Crippa et al (2019b).

N_r compounds	t/2000	t/2015	% Change
Ammonia - NH_3 emissions	42	64	52
Nitrogen oxides - NO_x emissions	3563	9576	169
Nitrous oxide - N_2O emissions	55	148	171

4.4 Reactive nitrogen emissions by sources

The total N_r emission produced by sectors highlight where action is needed to address the main sources. This section provides a breakdown of the driver/sources of N_r emissions in Maldives and compares the changes in emission levels.

4.5 Ammonia (NH_3) emissions

Ammonia (NH_3) is a key pollutant contributing to excess nitrogen deposition on vulnerable ecosystems[73] leading to acid deposition and eutrophication. NH_3 also features as a component of $PM_{2.5}$. Therefore, efforts to reduce ammonia directly would have co-benefits for mitigating $PM_{2.5}$ pollution[74].

According to the EDGAR data, NH_3 emissions in Maldives have been increasing more rapidly since 1993 and peaked in 2012-13. The reason for the peak in the data is unclear, it may have been due to a significant event and this needs to be further assessed. The overall findings show that in Maldives, agriculture is not a key source for NH_3 emissions, unlike the other South Asian countries where agriculture was the most prominent source. Data for Maldives show that there are a mixed number of sources for NH_3 emissions including electricity, heat production, transport, solid fuels and from other sectors.

The main contributions of NH_3 emissions are from buildings at 30%, followed by industrial combustion (23%) power industry (21%) transport (13%), waste sector (11%) and agriculture (2%) (see Figure 11). The low NH_3 emissions from agriculture is due to the country's limited agricultural productivity. Data from Table 6 reveals transport as the main emission source. Transport has undergone the highest increase, relative to other sectors, at 211% from 2000 to 2015. Table 7 gives a more detailed breakdown of the sub-sector sources. These results show that the transport sector should be prioritized for addressing N_r emissions.

For almost all sectors associated, NH_3 emissions have increased from 2000 to 2015, see Table 6, with the exception of agriculture which shows a decrease by (-46%). The biggest change was for transport[75], followed by the power industry (100% increase), and waste (94% increase), with contributions to NH_3 emissions, ranging from 21% and 11% respectively.

The NH_3 emission sector sources 'Buildings' and 'Other industrial combustion' had the highest overall contributions in 2015 followed by more modest increases from 2000 to 2015 of 18% and 31% respectively. These sectors also are highlighted as priority areas for main sources of NH_3.

[73] UNECE, (2021), Assessment report on ammonia, United Nations Economic and Social Council, UNECE, https://unece.org/sites/default/files/2022-07/Ammonia%20ECE_EB.AIR_WG.5_2021_7.pdf

[74] Wu, Y., Gu, B., Erisman, J. W., Reis, S., Fang, Y., Lu, X., & Zhang, X. (2016). PM2. 5 pollution is substantially affected by ammonia emissions in China. Environmental Pollution, 218, 86-94.

[75] 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.

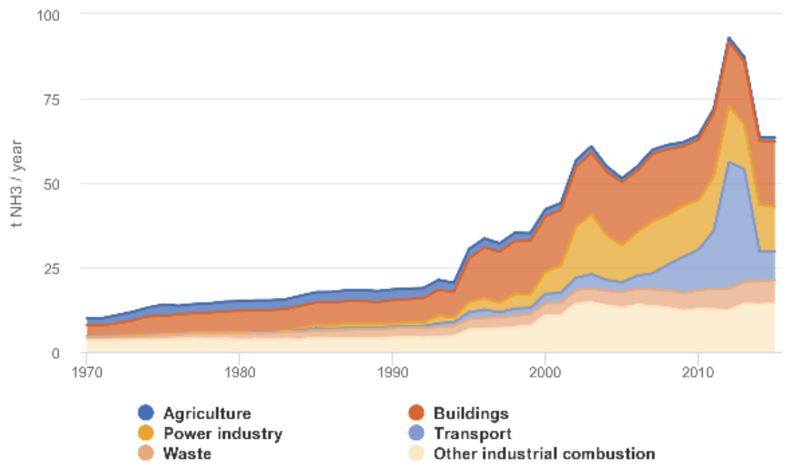


Figure 11: Maldives Ammonia (NH_3) emission trends by sectors from 1970 to 2015. Note: Data is sourced from EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019a)

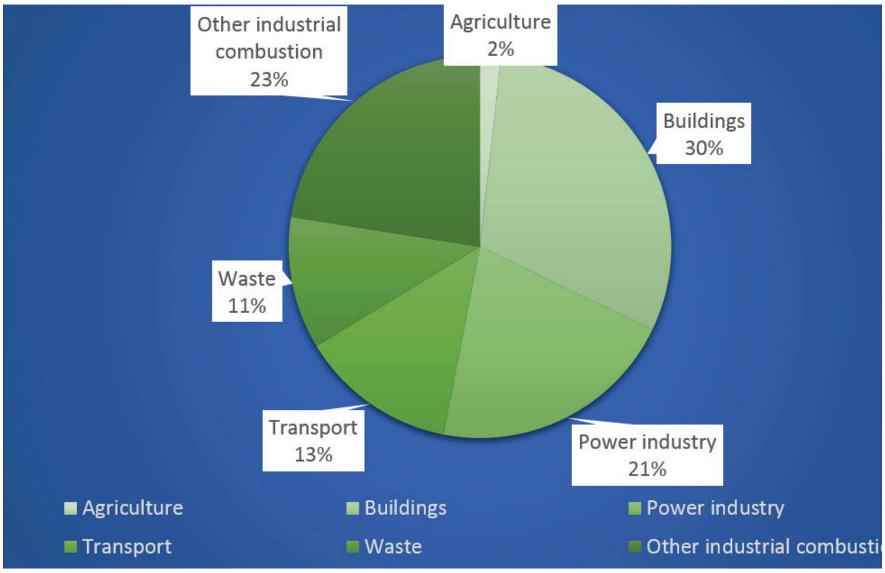


Figure 12: Maldives percentage of ammonia (NH_3) emission by sector in 2015. Note: Data is sourced from EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019a)

Table 6: Ammonia (NH_3) total emissions for 2000 and 2015 (tonnes/year) and percentage change for different sectors between 2000 and 2015 in Maldives

Tonnes per year	Agriculture	Buildings	Power industry	Transport	Waste	Other industrial combustion	Total
t/2000	2.09	16.28	6.66	2.71	3.66	10.92	42
t/ 2015	1.12	19.29	13.29	8.42	7.1	14.3	64
% change	-46	18	100	211	94	31	50
Note: Data is sourced from EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a)							

Table 7: Ammonia (NH_3) total emissions for 2000 and 2015 (tonnes/year) and percentage change for different sectors between 2000 and 2015 in Maldives

IPCC	IPCC description of sub sectors	Total emission tonnes/ 2000	Total emission tonnes/ 2015	% change (2000-2015)
Power Industry				
1.A.1.a	Main Activity Electricity and Heat Production	6.66	13.29	100
Other industrial combustion				
1.A.2	Manufacturing Industries and Construction	3.61	3.49	-3
1.B.1	Solid Fuels	7.31	10.80	48
Transport				
1.A.3.a	Civil Aviation	1.71	1.21	-29
1.A.b _noRES	Road Transportation no resuspension	0.97	7.10	632
1.A.3.d	Water-borne Navigation	0.02	0.07	250
1.A.3.e	Other Transportation	0.02	0.04	100
Buildings				
1.A.4	Other Sectors	16.00	19.04	19
Other				
1.A.5	Non-Specified	0.32	0.26	-19
Agriculture				
3.C.1	Emissions from biomass burning	1.15	0.64	-44
3.C.4	Direct N_2O Emissions from managed soils	0.94	0.48	-49
Waste				
4.C	Incineration and Open Burning of Waste	2.50	5.37	115
4.D	Wastewater Treatment and Discharge	1.16	1.73	49
Note: Data is sourced from EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a)				

4.6 Nitrogen oxides (NO_x) emissions

Nitrogen oxides (NO_x) are one of the dominating polluting compounds globally and in South Asia. Nitrogen oxides (NO_x) emissions have been increasing rapidly in Maldives since 2000. There was a high peak of NO_x emissions in 2002 and 2012. There was a decrease in 2005 which could be attributed to the 2004 Indian Ocean tsunami.

Data shows that the main sector sources for Maldives are the same as those for the other countries in South Asia, including road transport and electricity and heat production, see Figure 12 and 13. The main contributor for nitrogen oxides (NO_x) emissions in the Maldives is the transport sector (58%) followed by the power industry (39%). Other sectors only contribute marginally to overall NO_x emissions, these are, 'other industrial combustion' and 'buildings' contributing to (<2%).

The Ministry of Environment and Energy (MEE) projected that the nitrogen oxide (NO_x) emissions will increase over the upcoming years from 2010 (baseline) until 2030. Taking into consideration the population and economic growth, NO_x emissions are predicted to rise steadily under the business-as-usual scenario [76].

Prominent changes in NO_x emissions have been observed between 1999 and 2005, specifically for the transport sector, which shows a peak in 2012, see Figure 13. Emissions from the agriculture sector has shown to be decreasing over time (-48% between 2000 and 2015). Sectors that contribute mainly and have shown increases between 2000 and 2015 include the transport sector (318%) the waste sector (131%) and power industry (39%), see Table 8.

It should be noted here that road transport is not the main mode of transport in the Maldives. Due to the geographical setting of the country and the disbursed nature of the islands, marine transport is the key mode of transportation[77]. Aviation sector follows closely, as there have been significant developments in the recent years with the opening of regional airports in almost every atoll in the country. Road transport is used mainly on the larger islands of the country. The highest concentration of vehicles is in the capital city, Male'. The emissions from the sectors need further assessment and review with the key stakeholders in order to determine policy priorities to reduce NO_x emissions and air pollution.

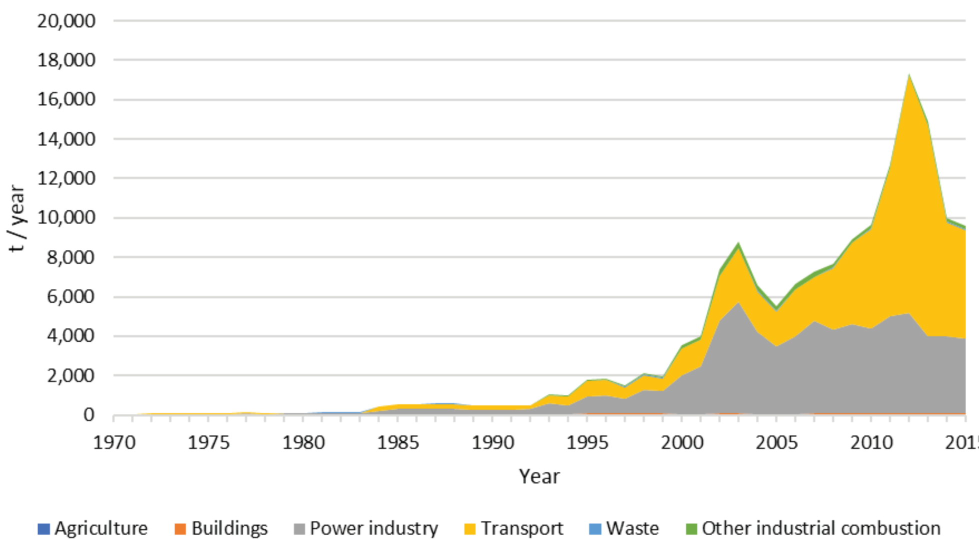


Figure 13: Trend in the NO_x emission by sectors over the years in Maldives Source: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a)

[76]Ministry of Environment and Energy. (2019). *National Action Plan on Air Pollutants: Determining Nationally Avoided Emissions. Male: Ministry of Environment.* Retrieved from https://www.ccacoalition.org/en/resources/maldives-national-action-plan-air-pollutants

[77]Ministry of Environment and Energy. (2014). *Low carbon strategy for transport sector.* Retrieved 4 October 2021, from https://www.environment.gov.mv/v2/wp-content/files/publications/20140930-pub-low-carbon-strategy-transport-sector-30sep2014.pdf

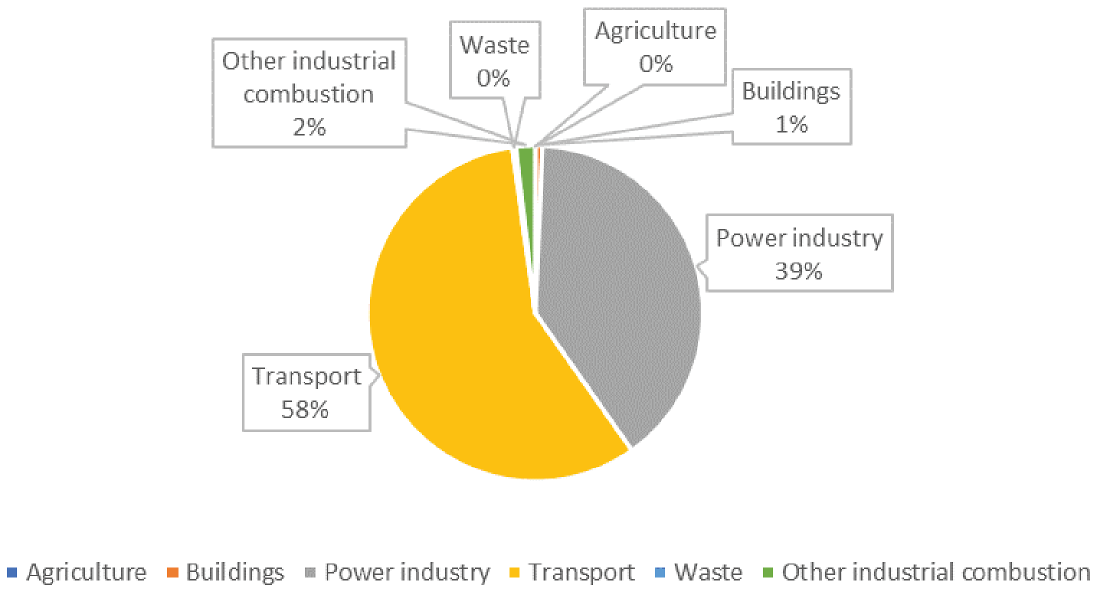


Figure 14: Maldives percentage of nitrogen oxides (NO_x) emissions by sector in 2015. Note: Data is sourced from EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019a)

Table 8: Nitrogen oxides (NO_x) total emissions in 2000 and 2015 and percentage change for different sectors between 2000 and 2015, Maldives

t/year	Agriculture	Buildings	Power industry	Transport	Waste	Other industrial combustion	Total NO_x
2000	4.72	40.64	1985.34	1319.17	14.92	198.4	3563.19
2015	2.47	64.24	3786.49	5511.67	34.47	176.77	9576
% change	-48	58	91	318	131	-11	169
Note: Data is sourced from EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a)							

Table 8: Nitrogen oxides (NO_x) emission in 2000 and 2015 (tonnes/year) and percentage change for different sectors between 2000 and 2015, Maldives

IPCC	IPCC description of sectors	Total emission tonnes/ 2000	Total emission tonnes/ 2018	%change (2000-2018)
Power Industry				
1.A.1.a	Main Activity Electricity and Heat Production	1990.00	3786.49	48
Other Industrial combustion				
1.A.2	Manufacturing Industries and Construction	198.00	176.58	-12
1.B.1	Solid Fuels	0.13	0.19	32
Transport				
1.A.3.a	Civil Aviation	1.40	1.32	-5
1.A.3.b_noRES	Road Transportation no resuspension	2.89	17.90	519
1.A.3.d	Water-borne Navigation	0.36	1.47	314
1.A.3.e	Other Transportation	0.10	0.33	240
Buildings				
1.A.4	Other Sectors	1.68	14.73	779
1.A.5	Non-Specified	0.16	0.37	130
Agriculture				
3.C.1	Emissions from biomass burning	0.06	0.04	-71
3.C.4	Direct N_2O Emissions from managed soils	1.33	1.05	-22
Waste				
4.C	Incineration and Open Burning of Waste	0.80	2.02	153
Note: Data is sourced from EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a)				

4.7 Nitrous oxide (N_2O) emissions

Nitrous oxide (N_2O) is one of six Greenhouse gases (GHG) targeted to be reduced under the United Nations Framework Convention on Climate Change (UNFCCC). Addressing Nitrous oxide (N_2O) would help deliver on both climate and ozone benefits[78].

N_2O emissions increased by 185% from 2000 to 2018 in the Maldives. The largest contributions from N_2O emissions have been recorded from 'indirect N_2O emissions from the atmospheric deposition of nitrogen in NO_x and NH_3 (at 88.70 t in 2018)', see Table 9. N_2O emissions from this source increased significantly since 2010 and spiked in 2013. These results contrast to the results of other South Asian countries where 'Indirect N_2O emissions from the atmospheric deposition of nitrogen in NO_x and NH_3 contributed to 8% of overall N_2O emissions in 2018, in comparison with 78% in 2018 for Maldives. Agriculture was found to be the biggest emitting sector source for the other South Asian countries, whereas for Maldives it is a fairly minor contributor (1%). Agricultural emissions, in contrast to other sectors, were also shown to be decreasing (-24%) from 2000 to 2018.

[78] Kanter, D.R., Ogle, S.M. and Winiwarter, W., (2020). Building on Paris: integrating nitrous oxide mitigation into future climate policy. Current Opinion in Environmental Sustainability, 47, pp.7-12.

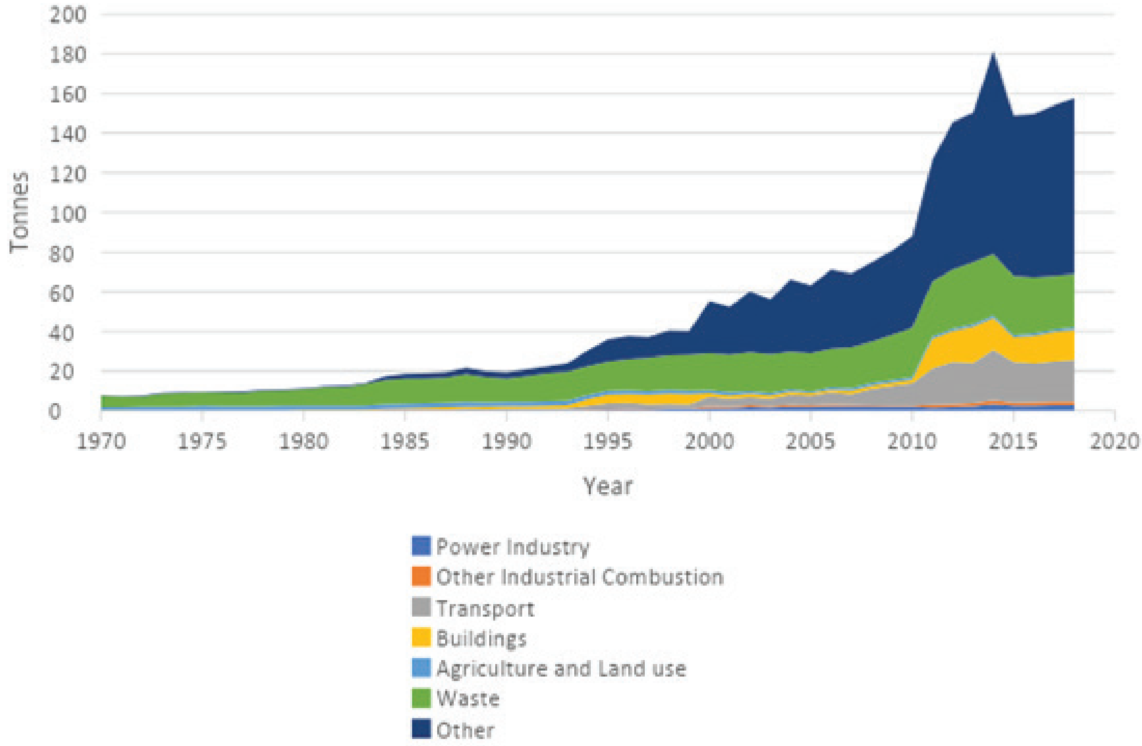


Figure 15: Nitrous oxide (N_2O) emission trends by sector sources in Maldives, from 1970 to 2018. Note: Data is sourced from EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b)

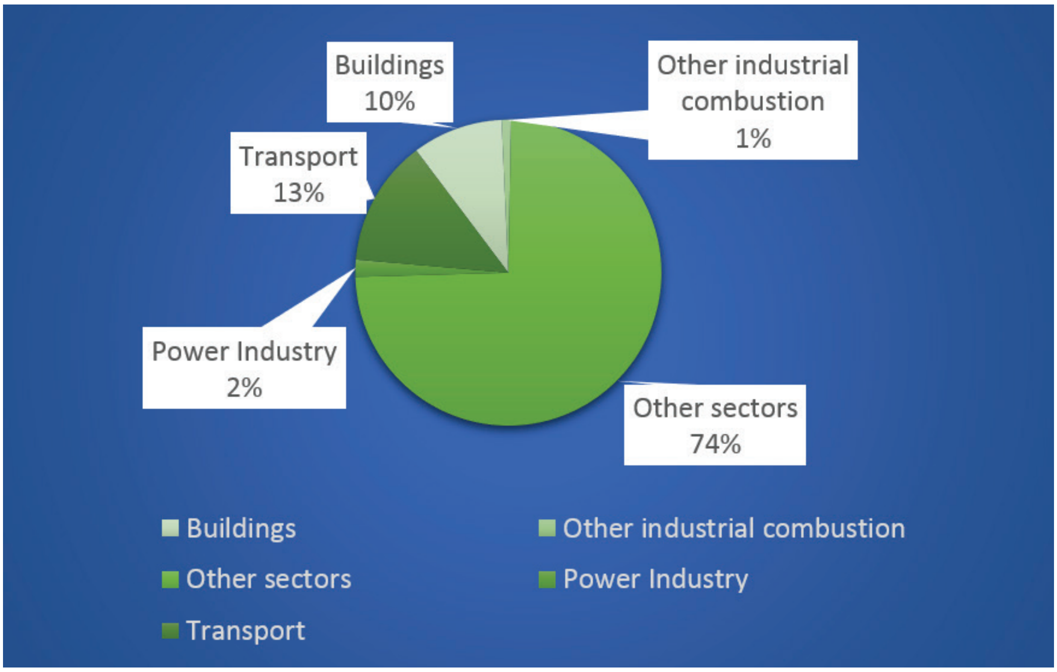


Figure 16: Percentage of nitrous oxides (N_2O) emissions by sector for Maldives in 2018. Note: Data is sourced from EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b)

Table 9: Nitrous oxides (N_2O) emission total tonnes for 2000 and 2018 for different sectors and percentage change between 2000 and 2018, Maldives. Note: Data is sourced from EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b)

	Sector							
t/year	Power Industry	Other Industrial Combustion	Transport	Buildings	Agriculture and Land-use	Waste	Other	Total
2000	1.38	0.94	4.74	1.84	1.55	18.62	26.16	55
2018	2.86	1.79	21.04	15.10	1.18	26.95	88.74	158
% change	107	90	344	721	-24	45	239	185

Table 10: Nitrous oxides (N_2O) emission for different sectors between 2000 and 2018, in total (tonnes per year) and percent change, Maldives. Data is sourced from EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b)

IPCC	IPCC description of sectors	Total emission tonnes/ 2000	Total emission tonnes/ 2018	% change (2000-2018)
Power Industry				
1.A.1.a	Main Activity Electricity and Heat Production	1.38	2.86	107
Other Industrial combustion				
1.A.2	Manufacturing Industries and Construction	0.80	1.54	92
1.B.1	Solid Fuels	0.05	0.11	109
2.G	Other Product Manufacture and Use	0.08	0.13	58
Transport				
1.A.3.a	Civil Aviation	1.40	1.32	-5
1.A.3.b_noRES	Road Transportation no resuspension	2.89	17.90	519
1.A.3.d	Water-borne Navigation	0.36	1.47	314
1.A.3.e	Other Transportation	0.10	0.33	240
Buildings Energy				
1.A.4	Other Sectors	1.68	14.73	779
1.A.5	Non-Specified	0.16	0.37	130
Agriculture /land use				
3.C.1	Emissions from biomass burning	0.06	0.04	-71
3.C.4	Direct N_2O Emissions from managed soils	1.33	1.05	-22
3.C.5	Indirect N_2O Emissions from managed soils	0.16	0.09	-44
Waste				
4.C	Incineration and Open Burning of Waste	0.80	2.02	153
4.D	Wastewater Treatment and Discharge	17.82	24.90	40
Other				
5.A	Indirect N_2O emissions from the atmospheric deposition of nitrogen in NO_x and NH_3	26.16	88.70	239

4.8 National reactive nitrogen emission results summary

- The results on N_r emissions for Maldives indicate that all three compounds of concern are on the rise and follow similar patterns to those identified for the South Asia Region
- 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 action is taken at international, national and local levels.
- Nitrogen oxides (NO_x) and nitrous oxide (N_2O) in Maldives are the fastest rising N_r compounds particularly since the year 2000.
- Emission levels for ammonia (NH_3) have been increasing steadily, with slight fluctuations since 1970's.
- The findings reveal differences between main sector sources for the different N_r compounds. For example, buildings are a major contributor to ammonia (NH_3) and transport for nitrogen oxides (NO_x) and for nitrous oxide (N_2O).
- The recent changes in N_r emissions indicate where there have been increases and decreases between certain sector sources.
- The changes in N_r emissions need to be considered with respect to the total contributions to identify any data gaps and where action is needed.

4.8.1 Ammonia (NH_3)

- For ammonia (NH_3), an ambient air pollutant, the sources of emissions were varied. The buildings had the largest contribution (30%), followed by the power industry (21%), road transportation (11%), wastewater treatment and discharge (8%) then manufacturing industries and construction (6%) are the main pollution sources and indicate areas where sustainable N_r management is required.

4.8.2 Nitrogen Oxides (NO_x)

- For nitrogen oxides[79] (NO_x), as an ambient air pollutant, the areas of main concern include the transport sector, with 'road transportation' and the 'power industry' as major contributors to overall emissions and with steeply rising emission levels evident in recent years. These two sectors require urgent attention to tackle and reduce nitrogen oxide (NO_x) emission levels in Maldives.

[79] which includes Nitrogen dioxide (NO_2) and Nitric oxide (NO)

4.8.3 Nitrous oxide (N_2O)

- For nitrous oxide (N_2O), as a GHG, the sector sources are fairly mixed, but unlike the results for the South Asia region agriculture is not a major source for the Maldives.
- The largest N_2O contributor are 'Indirect N_2O emissions from the atmospheric deposition of nitrogen in NO_x and NH_3 between 2000 and 2018. The main contributor is 'other' sectors with an increase of 239% in the same period.
- The transport sector had a sharp increase (344% from 2000 to 2018) in N_2O emissions and contributed to 13% of overall emissions. The transport sector as a key source for nitrogen oxides (NO_x) and as a source of ammonia (NH_3), this emphasizes the urgent need to take policy measures to tackle emissions from this sector.
- Wastewater treatment and discharge is a key contributing sector to emissions and also requires attention in policy to tackle rising N_r emissions.
- The building sector contributed (10%) to overall emissions and experienced the highest increase at 721% from 2000 and 2018, representing another sector that needs attention in nitrogen-related policy.
- The results indicate that different sectors contribute to the three N_r compounds dissimilarly and similarly. 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.

5. Major sectors

5.1 Agriculture

The acute smallness of land area in Maldives limits the available land to carry out agriculture. Maldives has the smallest total agricultural land area compared to the other South Asian countries (79km^2 in 2018)[80]. Agricultural land covers around 26% of the total land area of the Maldives. The arable land area of the country is approximately 2,800-3000 ha and about two-thirds of this (1800-2000 ha) falls in the agricultural land area in inhabited islands. However, according to the Ministry of Fisheries, Marine Resources and Agriculture (MoFA) this total estimate may not account for the area under homestead agricultural production. Figure 17 indicates the percentage of agricultural land for the total land area of each the South Asian countries for 2018.

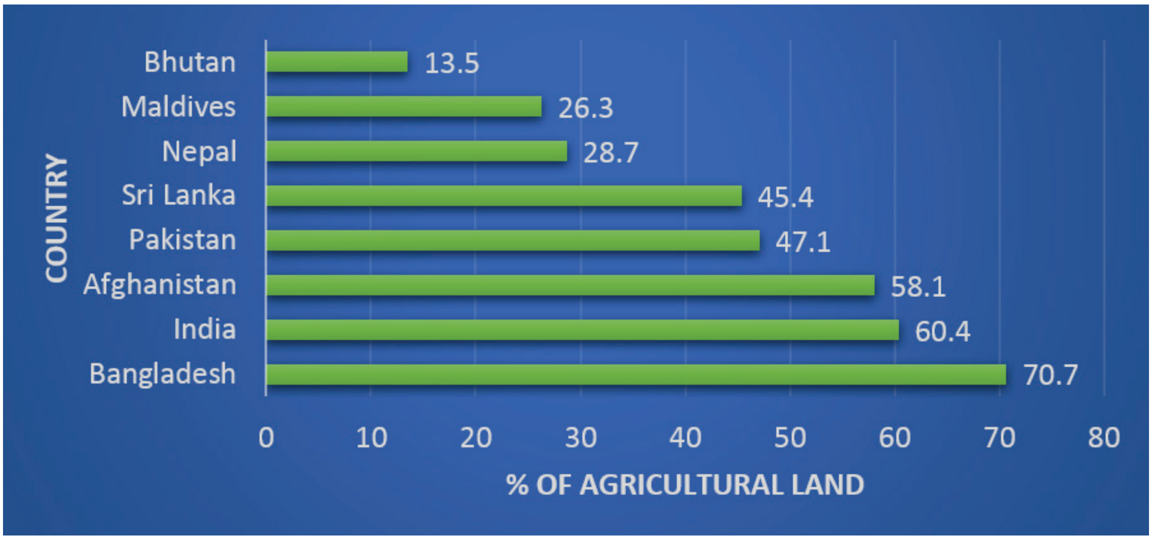


Figure 17: Percentage of Agricultural land per country in South Asia in 2018 (Source: World Bank, 2018) [81]

In addition, to the land allocated for agriculture in inhabited islands, there is a total of 5-40 ha of land from 50 uninhabited islands leased for agriculture and 8 islands for agriculture and fisheries purposes by the Government. These islands are operated by established entrepreneurs, and the production stability in terms of yield performance can vary, with some islands doing significantly poor than the others [82].

Livestock is rarely raised in Maldives except for a few poultry and cattle rearing projects in a few islands. Poultry without caged or fenced settings in inhabited areas are currently prohibited by law.

[80]World Bank. (2020). Agricultural land (sq. km) - Maldives. Retrieved March 23, 2022, from https://data.worldbank.org/indicator/AG.LND.AGRI.K2?locations=MV

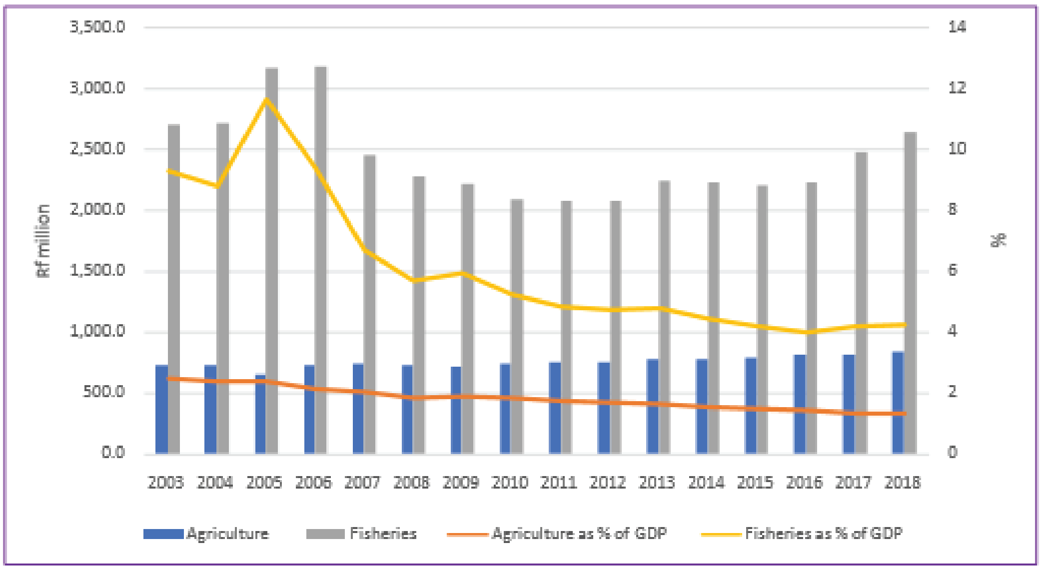
[81]World Bank. (2018). Agricultural land (% of land area) - South Asia | Data. Retrieved 24 October 2021, from https://data.worldbank.org/indicator/AG.LND.AGRI.ZS?locations=8S

[82]Mohamed, G. (2018). Agroecological analysis of Maldivian agricultural system to improve nutrient management (Master's Degree Programme). SLU, Swedish University of Agricultural Sciences.

The contributions of the agricultural sector to GDP have been declining since 2005, in 2018 the sector contributed to 4.2% of GDP (see Figure 18). However, it remains as a vital economic sector not only from a livelihood and employment perspective but also from the perspective of its potential to meet the increasing domestic demand. The HIES report[83], from 2016, estimates that the agriculture and forestry sector contribute to 2.3% of employment.

Since 2013, the agriculture sector has been gaining attention in terms of growth and stability in production. Statistics show that the value of agriculture production has been steadily increasing from 2003 to 2018 and the number of farmers after it dropped from 2013 to 2014, has been stable. There are 7,536 officially registered farmers in the Maldives[84].

The land utilized for agricultural activities has been increasing, but there is still land available for expansion since the land that is potentially cultivable is estimated to be 2,781 hectares[85]. Currently, only 573 hectares (about 20%) are being used for farming purposes. Therefore, there is potential for increasing agricultural production and safe and sustainable use of available natural resources should be promoted through policies and plans.



GDP = gross domestic product.
Source: National Bureau of Statistics. 2019. *Statistical Yearbook of Maldives*, 2019. Malé.

Figure 18: Primary Sector Production, 2003-2018

[83]International Labour Organisation., (2016). Household Income and Expenditure Survey 2016, https://www.ilo.org/surveyLib/index.php/catalog/7599

[84]Ministry of Fisheries, Marine Resources and Agriculture of the Republic of Maldives and FAO., (2021). National Fisheries and Agricultural Policy 2019-2029. [online] Gov.mv. Available at: <https://www.gov.mv/dv/files/national-fisheries-and-agricultural-policy-2019-2029.pdf> [Accessed 8 November 2021].

[85]National Bureau of Statistics. (2018). GDP Outlook – 2019, Statistical Yearbook 2019, Male', Maldives

Maldives imports approximately 90% of the food consumed in the country as it is not feasible to produce and supply the amount required to cater to the large tourism industry due to the land and geographical limitations[86]. The domestic demand for agricultural products has been increasing extensively, for example, the imports of fresh agricultural products have increased by 45% in value from 2014 to 2018, almost across the board especially for some vegetables, such as cabbage, lettuce, and snake gourd which have grown dramatically. In an effort to support food imports into the country, importers have been allowed 30% discount on import duties for any agricultural related inputs through the import regulation[87].

Agricultural activities are highly vulnerable to the effects of climate change. The risks include the rise in temperature, tidal waves, salt water inundation, precipitation, and flooding. Impacts on crops include stress on plants due to heat, changes in soil moisture and temperature, loss of soil fertility due to erosion of fertile topsoil, salinization of freshwater aquifer and loss of land through sea level rise[88]. The consequences of such impacts have the likelihood of increasing in the future and affect agriculture that is already under stress due to the poor condition of soil and limited availability of arable land.

Expanding agricultural production is further hampered by the lack of technical skills, capital, and investments and proper land utilization. To reduce and/ or resolve the issues faced by the sector, the government has established a state-owned enterprise, Agro National Corporation Pvt Ltd. in 2020. The corporation aims to pursue strategies for food security and self-sufficiency that boosts local production, facilitates value-addition in the agriculture sector, and explore overseas markets for local agricultural exports[89].

5.1.1 Crop production

The agriculture sector produces both food and vital non-food items such as timber, cordage, traditional medicines, and firewood in the Maldives. In many inhabited islands, field crops, such as sweet potato, taro, cassava, chili, watermelon, papaya, eggplant, green leafy vegetables, cabbage, gourd, and pumpkin are produced all year round. Seasonal crops such as mango, breadfruit, and drumstick fetch good prices in the market and contribute to the farmers' income[90].

In addition, various types of hydroponic systems have also been introduced and promoted by MoFA since 2001 as a means for climate resilient, water efficient, low-cost farming systems. Hydroponic systems are being used commercially and by community-based cooperatives and individual farmers to grow leafy vegetables such as lettuce (Lactuca sativa), kangkong (Ipomoea aquatica) and high-value crops such as cucumber (Cucumis sativus) and sweet melon (Cucumis melo). These systems are based on conventional imported hydroponics nutrient mixtures.

5.1.2 Fertilizer Imports, Use and Nitrogen emissions

In order to maximize agricultural production, vast amounts of organic and synthetic fertilizers are being imported. Fertilizer consumption pattern in the Maldives from 1961 to 2019 is shown to fluctuate from 2005 onwards until a gradual increase, evident from 2014 up to 2019 (See Figure 18). The main inorganic fertilizer import were products containing nitrogen, phosphorous and potassium (N.P.K) compounds. In 2018, the most used synthetic fertilizer product in the Maldives was of 'other nitrogenous fertilizers, n.e.c.[91].

[86]Climate Risk Country Profile: Maldives. (2021). The World Bank Group and the Asian Development Bank.

[87]Mohamed, G. (2018). Agroecological analysis of Maldivian agricultural system to improve nutrient management (Master's Degree Programme). SLU, Swedish University of Agricultural Sciences.

[88]IFRC, (2021), Climate Change Impacts On Health And Livelihoods: Maldives Assessment, International Federation of Red Cross (IFRC)

[89]AgroNAT. (2022). Agro Home. Retrieved March 5, 2022, from https://agronational.mv/en

[90]Ministry of Economic Development and UNDP, (2020). Impact of the COVID-19 crisis in the Maldives rapid livelihood assessment, UNDP

[91]n.e.c stands for not elsewhere classified.

Records from 2010 to 2019 show that there has been a 65% increase in organic fertilizer imports, as shown in Table 11. This indicates that, from 2010 onwards, Maldives has relied more on the use of organic fertilizers for food production (see Table 11).

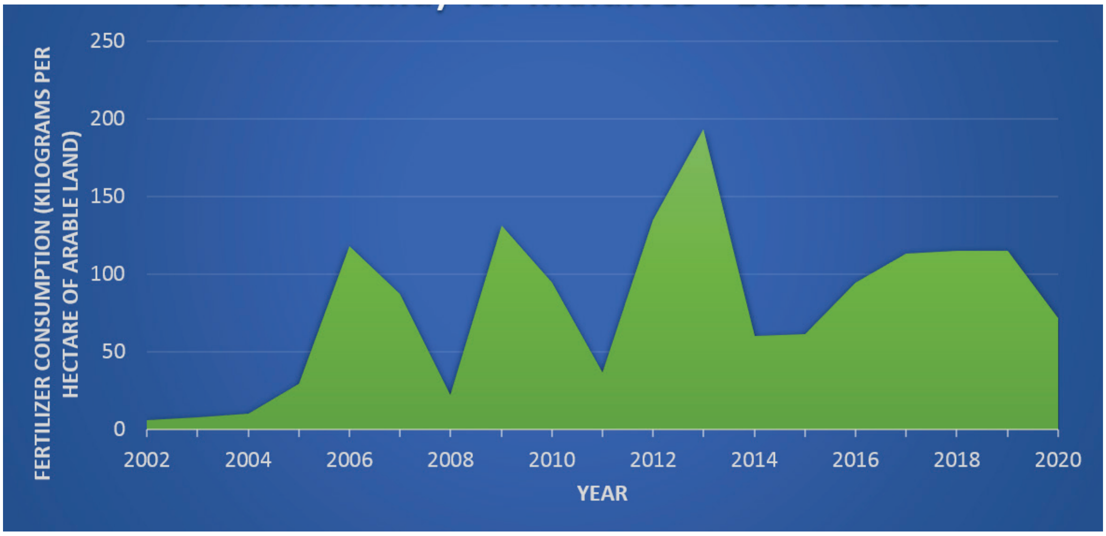


Figure 19: Fertilizers consumption pattern in nitrogen nutrients in the Maldives from 1961-2019. (Source: FAOSTAT, 2021)

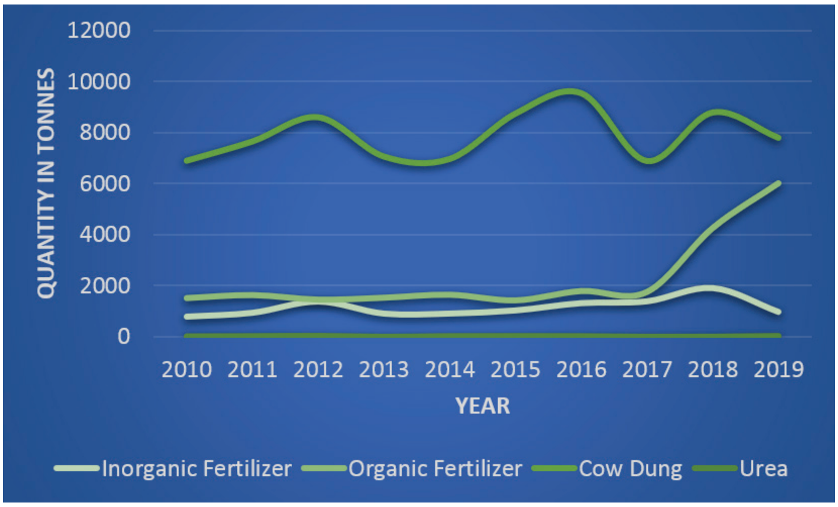


Figure 20: Total import of nitrogenous compounds in terms of fertilizers for Maldives from 2010-2019 (Source: Maldives Customs Services, 2022)

Figure 19 illustrates the total import of fertilizers between 2010 and 2019[92, 93]. When comparing the import quantity of inorganic and organic fertilizers, both types are shown to have remained at a constant supply with a sharp increase in organic fertilizer imports in 2017. Of the four types of nitrogenous compounds, import of cow dung is shown to have a gradual fluctuation but in general remaining the highest compound in demand over that time period.

[92]Maldives Customs Service. (2022). Customs Statistics. Retrieved 1 March 2022, from https://www.customs.gov.mv/Statistics

[93]Data is presented till 2019 as the data for 2020 and 2021 have the probability of deviating from the normal due to the Covid 19 pandemic restrictions.

Between 2010 and 2019, there has also been a considerable decrease in the imports of insecticides and fungicides with a -80 and -31 % change. The most significant change evident was the 11,690% increase in the quantity of herbicides, anti-sprouting products and plant growth regulators. It is also important to note that the import of pesticides under WHO toxicity classes are banned in the Maldives, except for few rodenticides[94].

Table 11: Breakdown of chemical types related to agricultural imports into Maldives for the year 2010 and 2019 (Source: Maldives Customs Services, 2022)

Chemical type		Quantity in Kg and Ltr combined		% change
		2010	2019	
Pesticides	Insecticides	1,235,269	250,276	-80
	Fungicides	12,427	8,614	-31
	Herbicides Anti-sprouting Products, Plant Growth Regulators	328	38,624	11,690
	Rodenticides	19,592	18,463	-6
Fertilizers	Organic fertilizers	8,406,197	13,832,557	65
	Inorganic fertilizers	778,977	967,109	24

According to the current farming practices, agrochemicals are excessively applied without paying attention to the manufacturers' set recommendations. This results in the addition of excessive concentrations of chemicals to the soil and plants. Misapplication of agrochemicals can lead to soil degradation, groundwater contamination, increase levels of nitrogen and phosphorus in the water leading to eutrophication and increase emission of GHG into the environment[95]. Without a proper assessment or monitoring system in place, it is not possible to determine the extent of the problems associated with fertilizer use.

There is also an urgent need to assess the farmer's knowledge and provide training on safe and effective farming practices including appropriate use of fertilizers. Organic fertilizers include naturally available mineral sources which are naturally sourced (manure/slurry) or processed, such as compost, blood meal etc. It was reported that the 'majority of organic fertilizers contain a balanced amount of raw nitrogen and thus work as slow-release fertilizers[96]'. For this reason, organic fertilizers are more likely than synthetic fertilizers, to contribute to sustainable N_r management when managed effectively. The reuse of nutrient rich waste (nitrogen recycling) as part of a circular economy, reduces N_r losses and maximizes synergies and minimizes trade-offs. Information and education programs should be developed and implemented to promote the use fertilizers appropriately to improve nitrogen use efficiency (NUE) in agriculture.

[94]MEE. (2016). Maldives National Chemical Profile 2015, Ministry of Environment and Energy

[95]MEE. (2017). State of the Environment 2016, Ministry of Environment and Energy

[96]Shaji, H., Chandran, V. and Mathew, L., (2021). Organic fertilizers as a route to controlled release of nutrients. In Controlled Release Fertilizers for Sustainable Agriculture in New Generation of Organic Fertilizers, ed. M.

The Government states a target to sustainably manage fertilizers, insecticides, pesticide, and excess nutrients by 2017[97]. Successive actions to reach the target includes developing the necessary regulatory framework and introducing certification system for sustainable agriculture. There is a need to assess further the available data and clarify the situation of fertilizer use in agriculture to determine accuracy of the information available and determine national level actions.

5.2 Transport Sector

The transport sector is the most important sector of the Maldives as it is the "lifeline" to the economy and to the rest of the world. Transport is also one of the biggest challenges in the Maldives due to the archipelagic nature of the country. As the islands are widely distributed, moving between islands often means moving across water. Maritime transport is the main mode of transport and the most affordable; as such it is opted more frequently than domestic aviation[98]. As stated in the Road map for the energy sector (2020 – 2030), all inhabited islands are connected by a basic nationwide transportation network of ferries. The number of registered marine vessels increased to 50% between 2010 and 2018[99].

Recent developments in the aviation industry include the opening up of new regional airports. The number of seaplane service providers and the size of fleets have also increased significantly over the recent years in order to cater to the growing demands from the tourism sector. The world's largest seaplane fleet, Trans Maldivian Airways Maldives, caters for domestic aviation in the country for tourists and the general public. These changes may be significant in effecting the dynamics of the industry in the near future. The transport sector is the fifth largest industry that contributes to the GDP of the country[100].

There are a few islands in the Maldives that are big enough for land transport services. In the recent years there have been shifts in residence of the population from outer islands to Male' City (Greater Male' Region), which caters to about 78,925 people (in 2014). As a result, the number of vehicles used in Malé City have grown extensively. Fuel consumption for land transport records show that it is mostly concentrated in the Greater Male' Region, where the number of registered vehicles has more than doubled in the period 2010–2018, with motorcycles accounting for 83% of all vehicles with an active registration in 2018[101]. The extreme congestion in Male' city with closely crammed high-rise buildings and high levels of vehicle emissions have led to the rise in air pollution rate in the city[102]. Statistics show that there are more than 68,000 two wheeled vehicles (motorcycles) and 3,000 four wheelers registered in Malé City, equivalent to two vehicles per resident in the city[103].

The number of registered sea vessels has grown by 515% from 2008 to 2018, and land vehicles increased by 215% from 34,416 to 108,532. As a result, the energy consumption rate and pollution rates by the vehicles have been on the rise. However, information to determine the energy efficiency of the transport vessels are not available and carbon dioxide (CO_2) emissions from transport are not being measured[104].

[97] MEE. (2015). National Biodiversity Strategy and Action Plan 2016-2025 Maldives: Ministry of Environment and Energy

[98] Fenhann, J. V., &Ramlau, M. (2014). Maldives Low Carbon Development Strategy. UNEP Risø Centre, Technical University of Denmark.

[99] ADB. (2020). A Brighter Future for Maldives Powered by Renewables: Road Map for the Energy Sector 2020–2030. Asian Development Bank. doi:10.22617/tcs200355-2

[100] Trans Maldivian Airways (Pvt) Ltd. (2022). Trans Maldivian Airways - The World's Leading Seaplane Operator. Retrieved 9 June 2022, from https://www.transmaldivian.com/#:~:text=Trans%20Maldivian%20Airways%20is%20your,to%20your%20island%20holiday%20destination.

[101] ADB. (2020). A Brighter Future for Maldives Powered by Renewables: Road Map for the Energy Sector 2020–2030. Asian Development Bank. doi:10.22617/tcs200355-2

[102] Ministry of Environment. (2019). National Action Plan on Air Pollutants: Determining Nationally Avoided Emissions. Malé: Ministry of Environment. Retrieved from https://www.ccacoalition.org/en/resources/maldives-national-action-plan-air-pollutants

[103] Corporate Maldives. (2019). Vehicles make up over 50% of Malé' roads: Ministry. Retrieved from https://corporatemaldives.com/vehicles-make-up-over-50-of-Malé-roads-ministry

[104] ADB. (2020). A Brighter Future for Maldives Powered by Renewables: Road Map for the Energy Sector 2020–2030. Asian Development Bank. doi:10.22617/tcs200355-2

5.2.1 Transport sector reactive nitrogen (N_r) emissions

Transport is one of the main contributing sources of nitrogen oxide (NO_x) and ammonia (NH_3) emissions in Maldives. NO_x transport emissions between 1970 and 2015, are illustrated in Figure 21. The data from EDGAR show that transport is the largest contributor to NO_x emissions and NO_x emission has increased rapidly since around 2008.

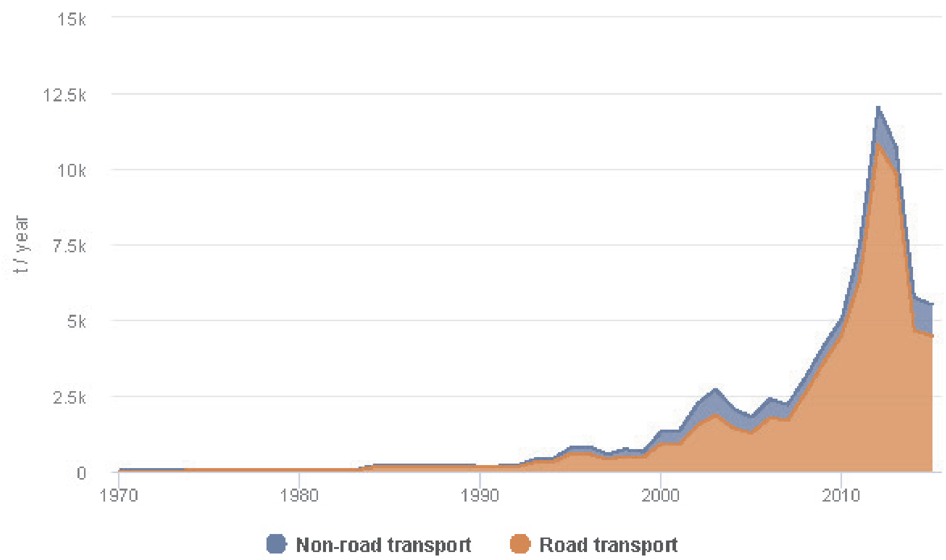


Figure 21: Nitrogen oxides (NO_x) road transport emissions (road transport and other transport) between 1970 to 2015 (As in Fig. 11)

A significant increase is evident in recent decades for both sea and land transport consequently leading to GHG emissions to increase alongside population growth and consequent rise in demand for vehicles. In terms of land transport, according to a press release in 2019 by the Ministry of Transport and Civil Aviation, 50% of the roads in Male' City consist of vehicles.

Table 12: Total vehicle registers in Maldives for 2008 and 2018 (Source: Statistical Pocketbook Maldives 2016 and 2020 [105])

Mode of transport	2008	2018	% Change
Sea	2,275 [106]	14,003 [107]	515
Land	34,416	108,532	215

Table 12 shows the trend of total vehicle registers for the year 2008 and 2018 in Maldives. As of 2019, 600 motorcycles were registered every month. Statistics show that there are more than 68,000 two wheeled vehicles (motorcycles) and 3,000 four wheelers registered in Malé city, equivalent to two vehicles per resident in the city[108].

[105] Maldives Bureau of Statistics. (2020). Statistical Pocketbook of Maldives 2020. Retrieved 15 November 2021, from http://statisticsmaldives.gov.mv/statistical-pocketbook-of-maldives-2020

[106] Inclusive of yacht dhonis, launches and boats

[107] Inclusive of Safari vessels, launches, boats and dhonis

[108] Corporate Maldives. (2019). Vehicles make up over 50% of Male' roads: Ministry. Retrieved from https://corporatemaldives.com/vehicles-make-up-over-50-of-male-roads-ministry

5.3 Fishery sector

The Maldives fishery industry has undergone major changes following the mechanization of the fishing vessels beginning in 1974. Traditionally, fishermen used 'Masdhoni', locally built wooden vessels. The fishing fleet used currently is a mix of wooden hulled and fibre reinforced plastics vessels powered by diesel engines. The modification and mechanization of the fishing fleet led to significant developments in the tuna fish industry that resulted in increases in the fish catch rates and efficiency in operations.

Maldives is a tuna fishing nation with a long tradition dating back hundreds of years. Until the 1980s the tuna fishery was the mainstay of the Maldivian economy, providing employment and a source of protein for its inhabitants. Tuna remains the single most important export commodity from the Maldives earning about 160 million US$ a year. Although the extensive growth and expansion of tourism in the country seem to have weakened the economic importance of fisheries, tuna fishing continues to be the main economic activity in the outer islands[109]. The fishery sector currently contributes around 3% to GDP in 2019. However, this estimate does not include the value of the fish processing industry, which is included under the manufacturing sector[110].

Tuna fisheries provide direct employment for approximately 20% of the population and it is estimated that 14,100 people are involved in full time fishing activities, and thousands more in post-harvest, boat construction and maintenance activities[111]. It is estimated that the sector contributes to 6.7% of total employment, with men dominating 97% of the employment in the industry[112].

The total tuna catches reached a record high of over 167,000 t in 2006. This was followed by a 53% decline in catch until 2010. Records reveal that tuna catches have since been increasing, 2017 recorded a 37% increase from 2010. This corresponds to an increase in the volume of fish purchases over the recent years till 2019, with skipjack tuna contributing significantly to the volume purchased. The main types of fish catch and exports in the country are skipjack tuna, yellow fin tuna and big eye tuna[113].

5.3.1 Fishery sector and reactive nitrogen (N_r) emissions

In terms of connecting the fisheries sector to N_r management, several studies have highlighted that fishing activities are the most energy-intensive step in seafood production, typically responsible for 75-90% of total energy use and GHG emissions studies. Globally, marine capture fisheries used an estimated 42.4 million tonnes of fuel in 2005, estimated at an annual expenditure of $22.5 billion; this is compared to 1.2% of global fuel consumption (as of 2000) estimated to of released 134 million tonnes of CO_2[114]. The trends in fluctuations in fish catches reflected in the number of fishing trips and the total diesel used (toe) from 2010 to 2017 are presented in Table 30 (see appendix). The data is further supported by figures shown in Table 13 on the energy consumption by fishing vessels of maldives in 2010, 2012 and 2017. The energy consumption by fishing vessels of Maldives from 2010 to 2012 is shown to have decreased.

[109] Ahusan, M., Adam, M. S., Ziyad, A., Shifaz, A., Shimal, M., & Jauharee, R. (2018). Maldives National Report Submitted to The Indian Ocean Tuna Commission Scientific Committee - 2018. IOTC. Retrieved February 10, 2022, from https://www.iotc.org/documents/SC/21/NR16

[110] Ministry of Economic Development, (2020), Impact of the COVID-19 Crisis in the Maldives, Ministry of Economic Development and UNDP

[111] Jauharee, A. R., Neal, K. and Miller, K. I. (2015). Maldives tuna Pole-and-line Tuna Fishery: Livebait Fishery Review, MRC, IPNLF and MSPEA, December 2015. 60 pages.

[112] National Bureau of Statistics. (2018). Household Income and Expenditure Survey (HIES) Analytical Report: Household Income 2016. Retrieved March 23, 2022, from http://statisticsmaldives.gov.mv/nbs/wp-content/uploads/2016/03/HIES-Report-2016-Income-Updated.pdf

[113] FAO. (2019). Fishery and Aquaculture Country Profiles:2019 The Republic of Maldives. Retrieved March 30, 2022, from https://www.fao.org/figis

[114] Miller, K., Adam, M. and Baske, A., (2017). Rates of Fuel Consumption in the Maldivian Pole-And-Line Tuna Fishery. IPNLF's Technical Series. [online] Available at: https://ipnlf.org/perch/resources/rates-of-fuel-consumption-in-the-maldives-pole-and-line-tuna-fishery-lr.pdf [Accessed 10 November 2021].

Table 13: Energy consumption by fishing vessels of Maldives in 2010 (Source: Maldives Energy Authority, 2014 [115], & National Bureau of Statistics, 2018 [116]).

	2010	2012	2017
Number of fishing trips	152,193	139,622	140,593 (116)
Total diesel used (toe)*	26,990	24,761	501,912 (117)
*Tonnes of Oil Equivalent			

5.4 Construction industry

The construction sector plays an important role in delivering basic to advanced infrastructure needed for the socio-economic development. From 2002, the construction sector's contribution to GDP increased from an average of about 6% to 9% in 2012. Construction activities doubled from 2014 to 2018, and the share of the industry in the GDP increased at an average annual growth rate of 14.6 % throughout 2014-2019. The annual percentage share of the construction industry in 2019 was at 6.4 % of the GDP.

The sector also witnessed significant growth during the period 2004 – 2008 with a recorded average annual growth rate of 25%, much higher than the average of around 11% during 1996 – 2000. Significant construction projects were carried out during this period including the Hulhumalé development project, reconstruction projects following the 2004 Indian Ocean tsunami and resort development activities. However, there was a sharp decline in the activities of the sector in 2009 due to the adverse impacts of the Global Financial Crisis (GCF) and the tsunami reconstruction almost reaching an end in 2008. Construction activities increased momentum from 2014 to 2018 and this coincides with the increase in N_2O levels in the year 2015.

A slowdown was again experienced in the sector in 2019 with the completion of several large infrastructure projects in 2018, and due to delays in commencement of the new Public Sector Infrastructure Projects (PSIP) budgeted for 2019[118].

[115] Maldives Energy Authority, (2014). Maldives Energy Supply and Demand Survey 2010-2012 – October 2014. [online] Utility Regulatory Authority. Available at: <https://www.ura.gov.mv/en/downloads/maldives-energy-supply-and-demand-survey-2010-2012-october-2014/> [Accessed 14 November 2021].

[116] National Bureau of Statistics. (2018). Statistical Yearbook 2019, Retrieved 7 March 2022, http://statisticsmaldives.gov.mv/yearbook/2018/wp-content/uplaods/sites/5/2018/12/9.10.pdf

[117] Bansal, S., Raghuram, N., Adhya, T., Rahman, M., Tshering, D., &Dahal, K. et al. (2022). Long-term trends of direct nitrous oxide emission from fuel combustion in South Asia. Retrieved 25 April 2022, from https://iopscience.iop.org/article/10.1088/1748-9326/ac5cf7

[118] The Ministry of Economic Development, & UNDP. (2020). Rapid Livelihood Assessment Impact of the Covid-19 Crisis in the Maldives. Retrieved February 20, 2021, from https://www.undp.org/sites/g/files/zskgke326/files/publications/UNDP-MV-Rapid-Livelihood-Assessmentt-Impact-of-COVID-19-Crisis-in-the-Maldives-2020-Part-III.pdf

5.4.1 Construction industry's reactive nitrogen (N_r) emissions

Construction industry is a key driver of N_r emissions for the Maldives. N_r emissions from the sector are shown to increase from 2000 to 2015 for all three N_r compounds (NH_3, NO_x and N_2O). N_2O emissions experienced a spike of 1630 t/year from 2000-2015 (see Table 14)[119].

Table 14: Nitrogen emissions from buildings between 2000 to 2015 (Maldives). 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)

Year	Ammonia (NH_3) emission (Gg year-1)	Nitrogen oxides (NO_x) emission (Gg year-1)	Nitrous Oxide (N_2O) emission (Gg year-1)
2000	16.28	40.64	390
2015	19.29	64.24	2020

5.5 Energy

Geographical dispersion of the islands in Maldives poses several challenges including services delivery. For provision of electricity, each island is required to have an individually operated power house. Despite the numerous challenges faced in the sector, Maldives achieved universal access to electricity in 2008[119]. A total of about 290 megawatt diesel generators have been installed in 187 inhabited islands (resort islands have an additional 144MW and industrial islands about 20MW)[120]. Imported diesel, shipped in small quantities by boat to islands, result in one of the highest costs for power generation in South Asia [121].

The country has experienced robust economic growth in the tourism, fishery industry, transport sectors leading to substantial developments in infrastructure and connectivity. As a result, energy demand has grown exponentially over the past four decades and is expected to grow annually by 8.5% out of which the greatest demand originates from Greater Male' Region[120]. Electricity generation is the largest consumer of imports in Maldives and fuel account for about 10% of the GDP and approximately half of the fuel imports are used for electricity generation. It is estimated that 723,000 tons of refined petroleum products were imported and used in the Maldives for varying purposes in 2019. Diesel accounted for 80% of the total imports and were used for electricity generation, industries (fisheries and water desalination) and sea transport. Petrol (12%) used mostly for road transport, Liquefied Petroleum gas (LPG) used for cooking and water heating and aviation fuel (6%) were used in the aviation sector [121].

The national energy needs are almost solely met by the use of fossil fuels. The main source of energy is oil and 4% renewables (in 2018, as stated in the Road Map for the Energy Sector 2020 - 2030). Reversing dependency on imported fuel is a key priority of the Government to improve energy security of the country. The Government in association with the development partners and donor agencies have amplified investments to achieve the vision outlined in the Road Map for the Energy Sector 2020 – 2030. The vision is "provision of sufficient, reliable, sustainable, secure and affordable energy for a prosperous Maldives." The vision is sustained on three pillars: energy efficiency, renewable energy, and integration of technology innovation. The Road Map establishes the guidelines for transitioning from a fossil-fuel-based sector to a cost-effective, business-competitive, affordable, and sustainable renewable energy. The target of the Government is to increase the share of renewable energy in the national energy mix by 20% (by 2023) compared to 2018 levels (4%)[121].

[119] Ministry of Environment. (2019). National Action Plan on Air Pollutants: Determining Nationally Avoided Emissions. Malé: Ministry of Environment. Retrieved from https://www.ccacoalition.org/en/resources/maldives-national-action-plan-air-pollutants.

[120] The Government of Maldives. (2019). Strategic Action Plan 2019-2023. Retrieved January 1, 2021, from https://presidency.gov.mv/SAP/

[121] ADB. (2020). A Brighter Future for Maldives Powered by Renewables: Road Map for the Energy Sector 2020–2030. Asian Development Bank. doi:10.22617/tcs200355-2

[122] Ibid

5.5.1 Reactive nitrogen (N_r) emissions from the Energy Sector

Electricity generation is highlighted as one the main sources of greenhouse gas (GHG) emissions for Maldives. Electricity and heat generation contributed to 40% of NO_x emissions and 21% of NH_3 emissions in 2015[123].

5.6 Waste management

Solid waste generation has increased in the Maldives significantly due to population growth, changes in consumption patterns, challenges in transportation and rapid growth of the tourism sector over the recent decades. The Greater Male' region [124] is responsible for a significant proportion of waste generation within the country[125].

Waste generated in Greater Male Region and other islands is transferred to Thilafushi on sea transfer vessels. Thilafushi was used as an open dump site with some sorting occurring on site. Plumes of smoke from open burning at Thilafushi has compromised air quality and is a nuisance to residents and tourists in the region. The open burning from Thilafushi has been stopped in 2020 through a joint initiative of the MoCCCT and WAMCO through assistance from the Greater Male' Environmental Improvement and Waste Management Project[126].

Open burning has been common practice as a means to reduce volumes of accumulating waste in the islands. Other poor waste management practices include dumping or burning waste at the island waste management centres located in the island periphery or the beach. Open burning of mixed waste can release high levels of toxic gases, deteriorating the air quality in the immediate vicinity and region.

Waste management projects are being implemented by the Government in six regions across the country. The aim is to establish safe and sustainable waste management systems with modern state of the art technology such as waste-to-energy systems. At the completion of the projects, it is expected that the environmental pollution would be reduced significantly[127].

5.6.1 Marine pollution

With rapid development leading to the increase in waste generation, marine ecosystems are likely to be negatively affected by land-based contamination as municipal and industrial waste are known to increase the Biological Oxygen Demand (BOD) of marine waters. Waste enters the marine environment when island communities dispose waste into the sea. Marine pollution is also caused by large quantities of nutrients released into the coastal waters by untreated sewage outfalls. Increases in the quantity of nutrient enrichments contribute to nutrient influx in the marine waters leading to algal blooms.

Marine pollution led eutrophication (also caused by excess N_r) have been affecting the water quality of the coastal waters in Maldives islands. Occurrences of 'Red tides' in the lagoons and beaches of some resorts in the recent years could be related to algal blooms. Incidents of mass fish kills have also been reported in recent years that may have links to poor water quality either related to changes in physical and chemical conditions of the marine environment, algal blooms, viral or bacterial infections or a combination of these factors[128].

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[123] EDGAR Database: https://edgar.jrc.ec.europa.eu/ 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

[124] Greater Male Region - Male', Vilimale, Hulhumale, Velana International Airport, Thilafushi and Gulhifalhu

[125] MEE. 2017. State of the Environment 2016, Ministry of Environment and Energy

[126] MoECCT. 2018. Greater Malé Environmental Improvement and Waste Management Project. Retrieved 14 June 2022, from https://www.environment.gov.mv/v2/en/project/8039

[127] Ibid.

[128] MEE. (2017). State of the Environment 2016, Ministry of Environment and Energy

Waste also reaches the marine environment as solid waste materials are washed away from landfills, thrown off from sea vessels and trans-boundary pollution. Trans-boundary pollution is a growing concern in the Maldives. The threats posed by trans-boundary pollution include marine debris and persistent organic and heavy metal pollutants that enter marine and coastal resources.

5.6.2 Reactive nitrogen (N_r) emissions from the waste sector

According to EDGAR data 'Incineration and open burning of waste' contributes to 8% of overall ammonia (NH_3) emissions in 2015. Figure 22 shows NO_x waste sector emissions from solid waste disposal and NH_3.

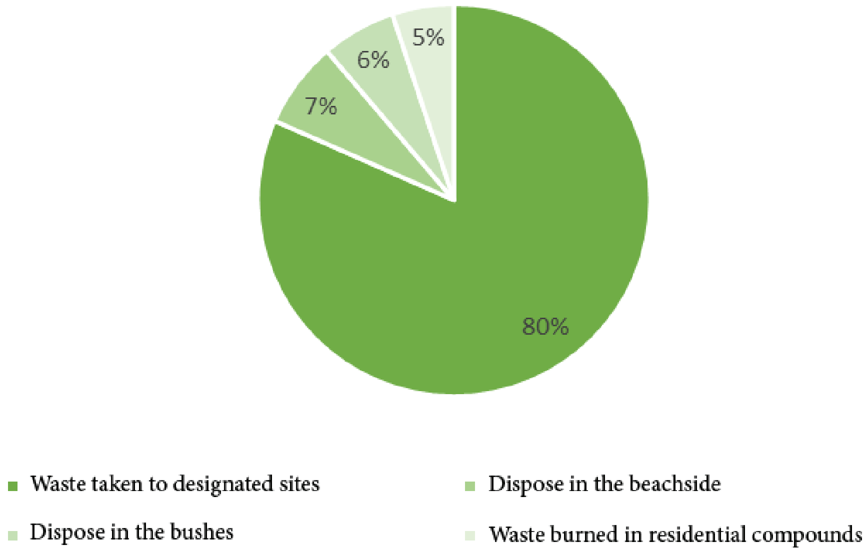

Figure 22: Waste management practices in Maldives in 2017 (Source: Maldives National Waste Accounts 2018 & 2019)

National records also show that wastewater treatment and discharge contribute to high Nitrogen emissions, in 2015 N_2O contributed to 16% of all emissions and 3% NH_3 emissions[129]. Figure 22 shows an analysis of 17 Environment Impact Assessment (EIA) reports with seawater samples providing results on the average amounts of nutrients present in these water samples. The average for the seawater pH was within the recommended average. Nitrates were recorded at borderlines to the highest averages recommended at 4.05mg.

[129] Ministry of Environment. (2019). National Action Plan on Air Pollutants: Determining Nationally Avoided Emissions. Malé: Ministry of Environment. Retrieved from https://www.ccacoalition.org/en/resources/maldives-national-action-plan-air-pollutants

5.7 Air pollution and reactive nitrogen (N_r) emissions

Emission of pollutants from natural sources and anthropogenic activities have negative impacts on the air quality, climate and human health. According to World Health Organization (WHO), 48 premature deaths per year, along with a wide range of respiratory and cardiovascular diseases are caused by negative health impacts from air pollution in the Maldives[130].

Atmospheric pollution that occurs over the Indian sub-continent has an impact on the rainwater of the area. This is concerning as 87% of the population relies on rooftop harvested rainwater for drinking. In December 2006, rainwater collected in Haa Dhaalu Kulhudhuffushi was found to be coloured even after filtration. In December 2011, Baa Eydhafushi and Vaavu Keyodhoo reported dark rainfall in the islands followed by another incident in Dhaalu Meedhoo in 2013[131]. The reason for the coloration of the rainwater is unknown.

Apart from black carbon and organic carbon, emissions of gases such as nitrogen oxides (NO_x), Sulphur dioxide, ammonia (NH_3) and organic compounds react in the atmosphere to form small particles that contribute to particulate matter ($PM_{2.5}$). Measuring long terms and short-term contributions of pollutants to air quality helps to understand the contributions in the country. Major health damaging pollutants include particulate matter ($PM_{2.5}$ and PM_{10}), ozone (O_3), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2). WHO provides guidelines with non-legally binding standards for each of these pollutants to help inform policies worldwide (see appendix Table 31). As one of a number of 'good practice' actions, emission inventories are recommended by the WHO. It was reported that the WHO limits of (PM) levels in Maldives were breached in 36% of cases caused by both domestic and long-range transboundary sources[132].

The first GHG inventory of Maldives was established in 1994, mainly focused on emissions from the energy and waste sectors[133]. The second inventory was conducted in 2011 and has since been able to perform a sectorial approach to establish the inventory. A study conducted by the UNEP in 2005 showed N_2O levels ranging between 350-650 µg/ton exceeded the standard limit set by the WHO at 35 µg/ton from the island of Thilafushi. Despite the progress over the past years, GHG emission inventories including air pollutants such as black carbon, fine PM, and NH_3 and others are yet to be established.

[130] UNEP. (2020). The Maldives and CCAC partnership: Tackling air pollution and climate change together. Retrieved 26 October 2021, from https://www.ccacoalition.org/en/news/maldives-and-ccac-partnership-tackling-air-pollution-and-climate-change-together

[131] MEE. (2017). State of the Environment 2016, Ministry of Environment and Energy

[132] Ministry of Environment. (2019). National Action Plan on Air Pollutants: Determining Nationally Avoided Emissions. Malé: Ministry of Environment. Retrieved from https://www.ccacoalition.org/en/resources/maldives-national-action-plan-air-pollutants.

[133] UNEP. (2005). MALDIVES Post-Tsunami Environmental Assesssment. Retrieved 12 May 2022, from https://postconflict.unep.ch/publications/dmb_maldives.pdf

6. National Level Nitrogen Policy Analysis

6.1 Methods Overview

This work builds on from an initial global nitrogen policy assessment conducted by Kanter and colleagues in 2020[134]. Their global database had a collection of 2,726 policies from across 186 countries derived from the ECOLEX database[135]. We adjusted the data collection approach and used multiple online data sources. We added to the 61 policies from South Asia identified by Kanter and colleagues from ECOLEX (2020) and created a new SANH policy database with a total of 966 policies for South Asia. This open access database is called 'Nitrogen-relevant policies from South Asia collected by the South Asian Nitrogen Hub (SANH) 2020-2021'. The policies were collected during 2020-2021. See table 15 for the overview nitrogen-relevant policies collected per country. Maldives-related policies contribute 4% to the overall policies collected for South Asia. The regional analysis of these polices are available in the SACEP-SANH report[136] and supporting journal article[137].

Table 15: Total Number of policies and percentage per country in the SANH database, breakdown by policy data source, and relevance and impact scope. Source: SANH Database[138]

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 web-sites	
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 Total	966	100	526	440	649
Percentages			55 %	46%	67%

[134] Kanter, D.R., Chodos, O., Nordland, O., Rutigliano, M. and Winiwarter, W., (2020). Gaps and opportunities in nitrogen pollution policies around the world. Nature Sustainability, 3(11), pp.956-963.

[135] Ecolex. (2021). The gateway to environmental law. Retrieved January 11, 2021, from https://www.ecolex.org/

[136] SACEP & SANH. (2022). South Asian Regional Cooperation on Sustainable Nitrogen Management, Nitrogen Pollution in South Asia: Scientific Evidence, Current Initiatives and Policy Landscape, SANH Policy Paper PP1, Colombo & Edinburgh

[137] Yang, A.L., Raghuram, N., Adhya, T.K., Porter, S.D., Panda, A.N., Kaushik, H., Jayaweera, A., Nissanka, S.P., Anik, A.R., Shifa, S. and Sharna, S.C. Joshi, R., Arif Watto, M., Pokharel, A., Shazly, A., Hassan, R., Bansal, S., Kanter, D., Das, S. & Jeffery, R. (2022). Policies to combat nitrogen pollution in South Asia: Gaps and opportunities, Environmental Research Letters, https://doi.org/10.1088/1748-9326/ac48b2

[138] Yang, A.L.; Adhya, T.K.; Anik, A.R.; Bansal, S.; Das, S.; Hassan, R.; Jayaweera, A.; Jeffery, R.; Joshi, R.; Kanter, D.; Kaushik, H.; Nissanka, S.P.; Panda, A.N.; Pokharel, A.; Porter, S.D.; Raghuram, N.; Sharna, S.C.; Shazly, A.; Shifa, S.; Watto, M.A. (2021). Nitrogen-relevant policies from South Asia collected by the South Asian Nitrogen Hub (SANH) 2020-2021 . NERC EDS Environmental Information Data Centre. https://doi.org/10.5285/e2f248d5-79a1-4af9-bdd4-f739fb12ce9a

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 23 provides an overview of the methods.

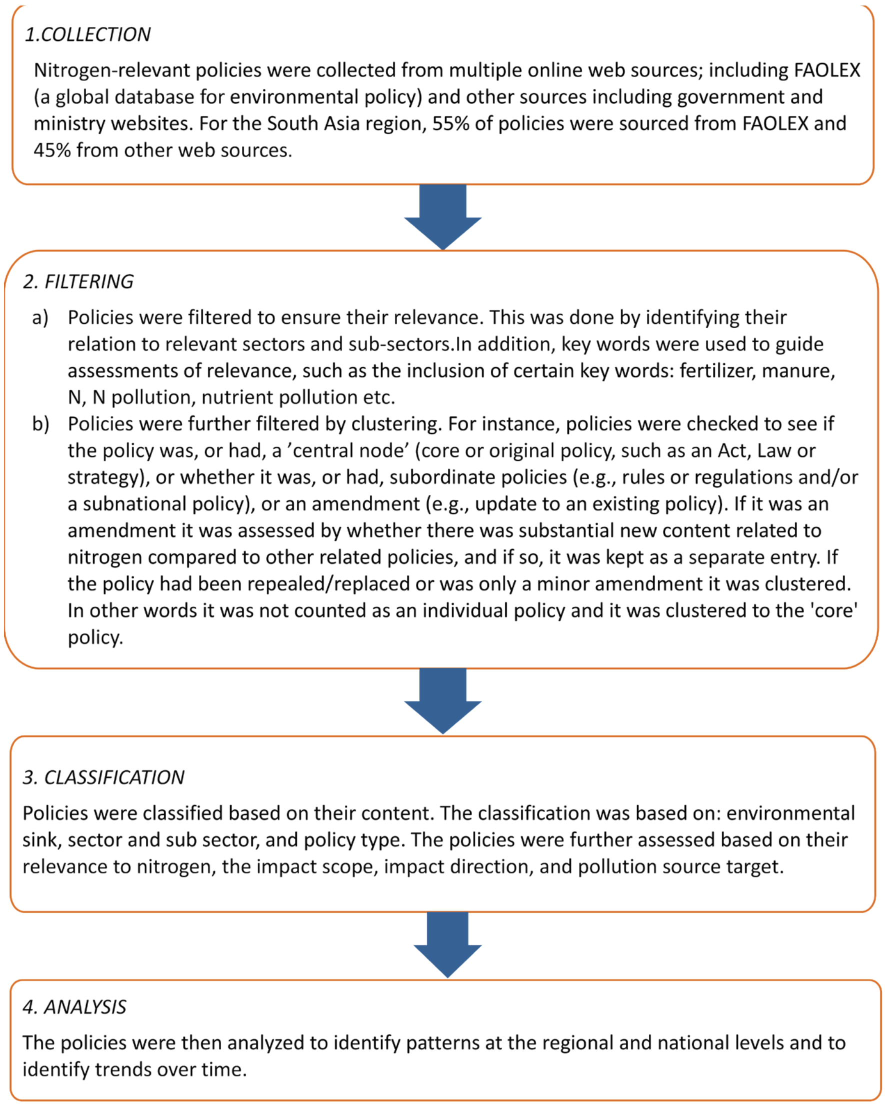

Figure 23: Overview of methods

6.2 Policy Classification

The nitrogen-related policies collected were classified based on certain characteristics to identify patterns in the types of policies 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 16. The classification approach followed somewhat closely the global study approach used by the global study with some adjustments and additional classifications. For classification definitions see Appendix, Table 32.

Table 16: SANH nitrogen–relevant policy classification lists

Categories	Classification	
Sink	Air; water; soil; climate; ecosystem; multiple; no sink included	
Sector	Agriculture	Synthetic fertilizer Manure management Crop residues Organic farming livestock Aquaculture Agriculture other
	Waste	Municipal waste Industrial/commercial waste Flood water Medical waste Organic waste
	Food	Food safety Food security Food waste
	Energy	Low carbon and renewable Non-renewable energy Biofuel and bioenergy
	Transport	Road transport Aviation Rail Maritime & inland water transport Transport other Biomass burning
	Land use change	Forestry Other land use and land use change
	Industry	
	Urban dev. & tourism	
	Other	
	Multiple	
	No sector included	

Policy type	Regulatory; economic; framework; data & methods; research & development (R&D); commerce; pro-nitrogen
Pollution source type	Point source; non-point source; both; unspecified; non-applicable
Impact direction	Positive; negative; mixed / neutral
Impact scope	Large; medium; small
Relevance	High; medium; low

7. Maldives SANH nitrogen related policy results

7.1 Relevance and scope

The nitrogen-related policies were classified according to their relevance and impact scope. These classifications were helpful for filtering policies with direct and indirect relevance to N_r management. By removing those policies classified as having low relevance or/and low impact scope (omitting 4 policies, 10%) this leaves a total of 36 policies. In other words, 90% of the total policies collected for Maldives can be considered of medium to high relevance and scope. Table 21 illustrates the number of policies and percentage classified as high, medium, and low relevance for N_r management. We defined directly relevant policies (aka those with 'high' relevance) by whether they featured one or more of the 29 key words in the policy text.

These 'selected' policies are assumed to have a greater impact on how N_r enters the environment. Those policies identified to have lower relevance and/or impact scope should, however, not be considered as irrelevant, as such policies still hold potential to have an impact via amendments to consider and mitigate N_r waste. For the purpose of better understanding, this section would reflect on the policies classified under high relevance and high impact scope only.

Table 17: Number and percentage of nitrogen-related policies in Maldives for relevance and impact scope

	Impact scope			
Relevance	Large	Medium	Small	Total
High	12 (30%)	6 (15%)	3 (8%)	21 (53%)
Medium	4 (10%)	7 (18%)	1 (3%)	12 (30%)
Low	1 (3%)	2 (5%)	4 (10%)	7 (18%)
Total	17 (43%)	15 (38%)	8 (20%)	40 (100%)

According to Table 21, the most common classification was recorded for high relevance and high impact scope at 30% (12 policies). The classification includes policies such as the 'National Biodiversity Strategy and Plan 2016-2025', the 'National Action Plan on Air Pollutants' and the 'Strategic Action Plan (SAP) 2019-2023.

7.2 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. framework, data and methods and research and development (R&D). For Maldives there were 66 policy classifications from the 40 policies. 19 policies (48%) had more than one policy type identified. Policies with multiple instruments are considered favourable since they indicate a more comprehensive approach.

Table 18: Number and percentage of nitrogen-related policies in Maldives for policy type

Policy Type	Total No. of policies	% of classifications
Regulatory	16	24
Economic	12	18
Framework	24	36
Data & methods	13	20
R&D	1	2
Commerce	0	0
Pro-N	0	0
Total	**66**	**100**

Table 18 illustrates the number and percentage of nitrogen-related policies in Maldives by policy type. The most common classification for policy type is identified as framework (36%). Such policies often include ones with broad objectives and/or designate governing bodies. For example, one framework policy is the 'Climate Change Policy Framework, 2015-2025'. The next most common classification is regulatory (24%), followed by data and methods (20%) and economic (18%). Regulatory and economic policies are considered 'core nitrogen policies' as outlined by Kanter et al (2020) 'as they directly address nitrogen production, consumption or loss in a measurable way'.

One of the least common policy type features in the dataset was research and development (R&D) which had only 1 policy (2%), the 'Maldives National Energy Policy and Strategy, 2010'. There were no policies found that featured commerce and Pro-N policy instruments.

7.3 Economic sector and subsector

Table 19 shows an overview of the total number of Maldives's nitrogen-relevant policies and percentages broken down by sector type and sub-sector type. Policies classified under multiple sectors were found to be the most common at 35%. This we considered a beneficial policy characteristic as to address N issues and its multiple sources requires an intersectoral and multisectoral approach. Some policy examples that did this include the 'Strategic Action Plan (SAP), 2019-2023' and 'Strategic Economic Plan, 2005'.

The second most common sector classification is waste and wastewater at 30%, followed by Industry (10%). The remaining sectors feature only as a small percentage each, ranging from 3% to 5%. Lastly, only a small percentage of (8%) of policies did not include reference to any sector, i.e., the policy is focused only on one or more environmental sinks. One such policy is the 'Supply water quality standard 2018'. While policies should ideally be linked to sector actions, sink oriented policies are still considered positive because they focus on environmental protection and sustainability actions.

Table 19: Number and percentage of nitrogen-related policies in Maldives for sectors and sub-sectors

Main Sector	No. of policies	% of policies	Sub-sector	No. of policies	% of policies
Agriculture	1	3	-	-	-
Waste & Waste Water	12	30	Municipal Waste	4	10
			Medical Waste	1	3
Industry	4	10	-	-	
Food*	1	3	Food safety	1	3
Energy	2	5	Low Carbon and Renewable Energy	1	3

Transport	0	0	Non-applicable*		
Land Use Change and Forestry*	0	0	Other Land Use And Land Use Change	3	8
Urban Development and Tourism*	2	5	-	-	-
Other*	3	8	-	-	-
Multiple	14	35			
No Sector Included	1	3			
Total	**40**	**100**	-	-	-

Note: For Other, Urban development and tourism, no sub-sectors were identified. For any main sector policy classified as 'Multiple' and 'NA', for sub-sectors they were by default classified as a non-applicable.

* Non-applicable represents general sector policy that do not specify a sub-sector

7.4 Environmental sinks

The classification for environmental sinks indicates if a policy is oriented in its objectives/intent towards either climate, water, air, soil, and/or ecosystems (see definitions in Table 37 in appendix). 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.

Policies referring to multiple sinks were the most common at 43% (refer Table 20). This is considered a highly favourable characteristic if the policies address two or more sinks, as its considering potentially multiple ways N could impact the environment. Policy examples include the 'Maldives Clean Environment Project Environmental and Social Assessment and Management Framework (ESAMF) and Resettlement Policy Framework (RPF), 2016', a policy which addresses and deals with all five sinks listed.

Table 20: Number and percentage of nitrogen-related policies in Maldives for environmental sinks

Sink type	No. of policies	% of policies
Water	5	13
Air	2	5
Ecosystems	3	8
Climate	1	3
Soil	0	0
Multiple sinks	17	43
No Sink Included	12	30
Grand Total	**40**	**100**

The most common single sink focus was on water (13%), for example the 'National Water and Sewerage Policy, 2017'. The other single sink policies (either air, ecosystems, climate or soil) had a low percentage of nitrogen-related policies associated with them (≤3%). A number of policies did not include any sink (30%) this is considered an unfavorable characteristic and reflects policies that only focus on a sector/s.

7.5 Pollution source type

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 recognizing 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. As shown in Table 21, 8 policies were classified under point source, some examples include the 'Drainage and Plumbing Regulations, 1996' and a policy for a specific location, the 'Environmental and Social Management Plan – Island Waste Management Centre in Lh. Kurendhoo, 2018'.

Non-point source (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. For Maldives, there were no policies identified under NPS singularly.

Although an environmental policy should recognize either point source or NPS, it is even more advantageous to consider both. This indicates a more comprehensive understanding of how N_r pollution can enter systems, recognizing that different approaches needed to tackle them. In the case of Maldives, 10% of the policies achieved this including the Maldives' Intended Nationally Determined Contribution (INDC), 2015' and the 'National Waste Water Quality Guidelines, 2007'.

The lowest classification of policies was categorized under 'unspecified' (13%) which included policies that neither reflected point source nor NPS. This could be a disadvantage for a policy's ability to support sustainable N_r management. Some of the policies classified as unspecified were the 'Regulation on the Protection and Conservation of Environment in the Tourism Industry, 2006', and the 'EIA data collection guideline, 2019'. However, such policies could be amended to consider types of pollution sources, as appropriate.

For Maldives, Non-applicable (NA) was the most common classification (43%) within this category. This was the default classification for policies classified with a negative impact direction, and/or as having an indirect relevance to nitrogen. For example, the 'National Food Safety Policy, 2017-2026' and the 'Business Registration Act (Law No. 18-2014)'.

Table 21: Number and percentage of nitrogen-related policies in Maldives for pollution type source

Pollution type source	No. of policies	Percentage of policies (%)
Point source	0	0
Non-point source (NPS)	8	20
Both pollution type sources	10	25
Unspecified	5	13
Non-applicable (NA)	17	43
Total	**40**	**100**

7.6 Impact direction

Impact direction was introduced as a classification by the SANH study 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, 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.

Table 22: Number and percentage of Maldives nitrogen-relevant policies for impact direction

	No. of policies	Percentage of policies (%)
Positive	25	63
Negative	0	0
Mixed /neutral	15	38
Grand Total	**40**	**100**

According to Table 22, it was promising that 63% of policies had a presumed positive impact i.e., it promoted a reduction in N_r pollution and/or improved nitrogen management whether directly or indirectly. This included mostly environmentally oriented policies such as the 'Environmental Impact Assessment Regulations, 2007 (5 amendment)' and the 'Maldives Energy Policy and Strategy, 2016'.

It was also encouraging to detect zero policies with a potentially negative impact, i.e., where environmental considerations were absent from the policy text. This would be an unfavourable policy indicator as such policies may have the potential to increase nitrogen waste, by causing excess N_r.

The last 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 consider the environmental impacts, or a policy that is potentially neutral in its impacts (i.e., neither positive nor negative). The remaining 38% of the policies were classified as mixed/neutral, a classification that covers a wide range of policies including those that may, or may not, lead to sustainable N_r management. Further assessments of all the policies would be needed to identify how far any of these policies could achieve sustainable outcomes in practice.

7.7 Selected policies for pollution source and impact direction

Table 23 illustrates the pollution source type with impact direction for the selected policies. Policies classified as positive have the largest percentage at 31% followed by mixed/neutral direction at 3% and no policies were classified with a negative impact direction for pollution source. Positive impact direction policies were commonly associated with both point sources (31%) i.e., representing favourable policy characteristics. Examples of policies in this classification include the 'National Waste Water Quality Guidelines, 2007' and the 'Maldives National Energy Policy and Strategy, 2010'. The second most common combination with positive impact direction policies were with point source (21%) with examples such as the 'National Water and Sewerage Policy, 2017' and the 'Environmental Guidelines for Concrete Batching Plants, 2016'.

For mixed/neutral impact direction policies (31%), the most common combination was classified as non-applicable (21%) with examples such as the 'National Food Safety policy, 2017-2026' and the 'Fisheries Act of the Maldives (No. 14/2019)'. Such policies may require attention to see how pollution sources could be more carefully considered. No policies were classified under NPS for impact direction.

*Table 23: Percentage of *selected Maldives nitrogen-relevant policies for pollution source and impact direction*

Impact direction	Both	Non-Point Source (NPS)	Point Source	Unspecified	Non-applicable	Total
Mixed /Neutral	3	0	0	3	21	28
Negative	0	0	0	0	0	0
Positive	31	0	21	10	10	72
Total	34	0	21	14	31	100
*selected policies are based on high–medium relevance and impact scope, a total of 29 policies						

7.8 Selected policies for sink and sector

Table 24 illustrates the selected policies comparing the classifications for sink and sector. Multiple sector and sink policies had the highest percentage by 24%. This includes, for example, 'Maldives Clean Environment Project Environmental and Social Assessment and Management Framework (ESAMF) and Resettlement Policy Framework (RPF) (2016)' and the 'Strategic Action Plan (SAP) 2019 – 2023'.

The second highest number of policies were recorded for the combination waste and waste water as a sector and no sink included at 17%. This includes the 'National Healthcare Waste Management Strategic Plan (2017)' and the 'Environmental Guidelines for site selection of Waste Management Centres (2017)'.

*Table 24: Percentage of *selected Maldives nitrogen-relevant policies for sink and sector*

	Sector								
Sink	Agriculture	Waste & Waste Water	Industry	Food*	Energy	Urban Development and Tourism*	Other*	Multiple	Total
Air	0	0	0	0	0	0	0	7	7
Water	0	10	0	0	0	3	0	0	14
Climate	0	0	0	0	3	0	0	0	3
Ecosystem	3	0	0	0	0	0	0	7	10
Multiple	0	7	3	0	3	3	0	24	41
No Sink Included	0	17	0	3	0	0	3	0	24
Total	3	34	3	3	7	7	3	38	100
*selected policies are based on high–medium relevance and impact scope, a total of 29 policies									

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

Sector	Regulatory	Economic	Framework	Data & Methods	R&D	Commerce	Pro-N	Total
Agriculture	2	2	0	0	0	0	0	4
No sub-sector included	2	2	0	0	0	0	0	4
Energy	0	2	4	0	2	0	0	9
Low Carbon and Renewable	0	2	2	0	2	0	0	7
Multiple	0	0	2	0	0	0	0	2
Food	0	0	2	0	0	0	0	2
Food Safety	0	0	2	0	0	0	0	2
Industry	2	2	0	2	0	0	0	7

Other Land Use	2	2	0	2	0	0	0	7
Multiple	4	2	17	7	0	0	0	
Multiple	4	2	7	0	0	0	0	
Other Land Use and Land Change	0	0	0	2	0	0	0	2
No sub-sector included	0	0	11	4	0	0	0	
Other	0	0	2	0	0	0	0	2
No sub-sector included	0	0	2	0	0	0	0	2
Urban dev. & Tourism	4	4	0	2	0	0	0	
No sub-sector included	2	2	0	0	0	0	0	4
Other Land Use and Land Change	2	2	0	2	0	0	0	7
Waste	13	4	11	7	0	0	0	
Multiple	2	0	7	4	0	0	0	
Municipal Waste	2	0	4	2	0	0	0	9
No sub-sector included	9	4	0	0	0	0	0	
Total	26	17	37	17	2	0	0	

*selected policies include those with high–medium relevance and impact scope, a total of 29 policies. The percentages are based on the total number of classifications, a total of 46 for the selected policies.

Note: Rows coloured in light blue indicate the main sectors and the subtotal for sub-sectors. The policies highlighted in pale blue include those that are above 3%.

7.9 Selected policies for sector, sub sector and policy type

Table 25 illustrates sectors and sub-sectors compared with policy type for the selected policies (filtered by relevance and impact scope). From an overall and single sector perspective, the majority of the combinations are focused on 'waste', as before, stands out as most common (35%). The most common policy types with those classified as waste were framework (11%), then regulatory (13%), data & methods (7%) and economic (4%).

The majority of the combinations are ≤2%. The second highest percentage is for policies where 'multiple' sectors are referred to (30%). The most common policy type for these multiple sector policies, similar to the results from the whole dataset, is framework (17%) and data & methods (7%).

Increasing the number of relevant policies for R&D would be recommended across the range of sectors, to support the discovery and testing of mitigation options for N pollution.

7.10 Policy Trends

The number of nitrogen–relevant policies in Maldives has been increasing over time. Table 26 illustrates policies established between 1990-2000, 2001-2010 and 2011-2019. Most nitrogen related policies (65%) were established in the 2011-2019 time period. The increasing trend in the number of policies between each decade shows that environmental management are increasingly being prioritized at the national level.

Table 26: Number and percentage of Maldives nitrogen-relevant policies between 2001-2010 and 2011-2019

Sector	No. of policies			% of policies		
	1990-2000	2001-2010	2011-2019	1990-2000	2001-2010	2011-2019
Agriculture	0	0	1	0	0	3
Energy	0	1	1	0	3	3
Food	0	0	1	0	0	3
Industry	1	0	3	3	0	8
Multiple	1	5	8	3	13	20
Other	0	0	3	0	0	8
Urban dev. & tourism	1	1	0	3	3	0
Waste	1	3	8	3	8	20
No sector included	0	0	1	0	0	3
Grand Total	4	10	26	10	25	65

7.11 Maldives standout policies

Policies that have included references to multiple sink and/or sectors and/or include multiple policy instruments, stand out as being those best able to support nitrogen management. There are two policies (10%) that hit all these criteria. These policies stand out as they refer to multiple sinks, sectors, and include multiple policy types. In addition, both these policies have been classified as being of high relevance and large impact scope. The two policies are:

1. Strategic Action Plan (SAP), 2019 - 2023.
2. Climate Change Policy Framework, 2015-2025

With reference to pollution source type, one of the requirements of policy characterization, all (n=4) policies have been classified as having both pollution types (point source and non-point source). These policies stand out further as policies with the strongest potential to deal with the complex nature of N management. The four policies are:

1. Strategic Action Plan (SAP), 2019 - 2023
2. Climate Change Policy Framework, 2015-2025
3. Maldives' Intended Nationally Determined Contribution (INDC) (2015-2030)
4. National Action Plan on Air Pollutants, 2019

7.12 Maldives policy development

Maldives has been at the forefronts of environmental protection since 1980's as marked deteriorations clearly demonstrated the need for environmental management and planning in the country. As shown in Figure 25 (see appendix), the formation of the South Asia Co-operative Environment Program (SACEP) in 1982 initiated the journey to promote and support the protection, management and enhancement of the environment in the region and for the country as well. And all the national policy changes were formulated and went hand in hand with the signing of international conventions, agreements and treaties as shown in Figure 26.

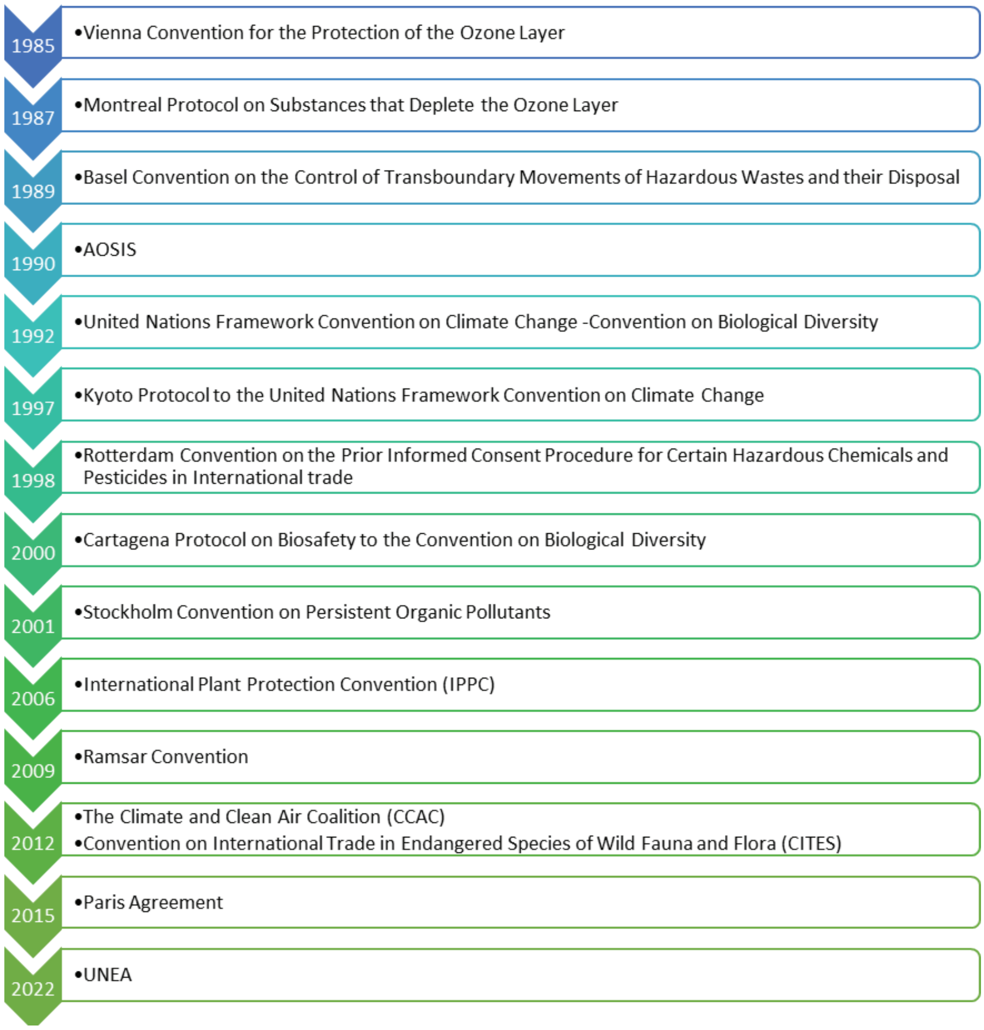

Figure 24: Timeline of international treaties/conventions/agreements to which Maldives is party to with respect to N management.

Figure 24 shows the international treaties/conventions/agreements to which Maldives has committed to with respect to N management. Concern over the sea level rising began to emerge in 1987 with record tides that led to the flooding of one third of the archipelago including the capital city Male' causing the government to analyze the cause of this rare phenomenon. The situation was clearly expressed at the Commonwealth Summit for Heads of State and Governments in Vancouver and United Nations at the same year and from the countries present at the summit, 26 were small island states experiencing unusual weather events. This instigated the earliest global call to climate action and for the establishment of a United Nations framework convention on climate change along with the official formation of the Alliance for Small Island States (AOSIS)[139].

Being the founding member of the (AOSIS) [140] in 1990, together with Trinidad and Tobago and Vanuatu, Maldives was able to lead the Alliance and produce outcomes such as the Sendai Framework for Disaster Risk Reduction, the Addis Ababa Agreement on Financing for Development, the 2030 Agenda on Sustainable Development and the Paris Agreement on Climate Change.

In 2002, President Gayyoom called on the international community to take urgent action to prevent global environmental catastrophe and warned low-lying islands were at greater risk than ever before. The 2004 Indian Ocean tsunami left many islands with severe damage and reports from the government implies a 20-year set back to the development of the country[141].

Maldives has ratified amendments brought in later years such as the Kigali amendment to the Montreal Protocol in 2016[142]. At the national level Maldives policies have also been changing. Furthermore, the policies go in line with changes in the government administration of the country equivalent to a 5-year term in Maldives. Maldives has come a long way in terms of environmental management in the past decades.

During the Fifth Session of the United Nations (UNEA-5), MNU presented findings based on the Air Quality Monitoring research project where MNU was involved with Duke University from United States, funded by the US Department of State. The main points included the present condition of the Maldives in terms of monitoring air pollution and how the research project will help achieve the crucial goals of the Maldives National Action Plan on Air Pollutants. The project aims to deploy 20 Low-cost TSI BlueSky air quality monitors/sensors across the country to monitor $PM_{2.5}$ levels. At present, with 6 sensors operating, the Greater Male' region sensor network has been established in the region. In addition, with the use of satellite images integrated with meteorological modelling and source apportionment, with added technical support from Duke University, national-scale monitoring would be established.

[139] AOSIS. (2021). AOSIS: A history of leadership at the UNFCCC - AOSIS. Retrieved 28 November 2021, from https://www.aosis.org/aosis-a-history-of-leadership-at-the-unfccc/

[140] AOSIS. (2021). AOSIS: A history of leadership at the UNFCCC - AOSIS. Retrieved 28 November 2021, from https://www.aosis.org/aosis-a-history-of-leadership-at-the-unfccc/

[141] BBC. (2018). Maldives profile - Timeline. BBC, p. 1. Retrieved from https://www.bbc.com/news/world-south-asia-12653969

[142] Ministry of Environment, Climate Change and Technology. (2016). Parties to the Montreal Protocol agree on Kigali Amendment to phase down HFCs. Retrieved 29 November 2021, from https://www.environment.gov.mv/v2/en/news/2776

8. Stakeholder overview

Stakeholders are defined as individuals or groups who have an interest and/or potential influence on N_r management. The list of stakeholders includes a broad range of participants with respect to multiple sector sources of N waste, along with susceptible human and environmental impacts.

Government Ministries have the mandate to develop and implement legislations, policies, regulations and plans that are related to the sectors within their mandate. Key National agencies in terms of N management include authorities responsible for agriculture, energy, transport and environment. In this regard, key Ministries in Maldives would be Ministry of Environment, Climate Change and Technology, the Ministry of Agriculture and Marine Resources and the Ministry of Transport and Civil Aviation.

The Decentralization Act (07/2010) of Maldives mandates the local councils (atoll and island councils) to protect the environment and to provide environmental management services to the island communities in line with the National policies and plan. The councils are the local Government representatives working under the guidance and support of the Local Government Authority (LGA) [143].

[143]Local Government Authority. (2022). Local Government Authority. Local Government Authority Maldives. Retrieved November 26, 2022, from https://www.lga.gov.mv/

Table 27: Preliminary Stakeholder overview for Maldives

Main groups	
Government Ministries and National Authorities	Ministry of Environment, Climate Change and Technology (MoECCT) Environmental Protection Agency (EPA) Ministry of Health (MoH) Ministry of Education (MoE) Ministry of Higher Education Maldives Meteorological Services (MMS) Local Government Authority (LGA) Utility Regulatory Authority (URA) National Disaster Management Authority (NDMA) Health Protection Agency (HPA)
Local government	4 Cities (Including the capital, Male' City) Atoll Councils Island Councils
International organizations/ agencies/donors	United Nations Development Program (UNDP), Food and Agricultural Organisation (FAO), International Fund for Agriculture Development (IFAD), World Health Organisation (WHO), United Nations Children's Fund (UNICEF), International Union for Conservation of Nature (IUCN) Development banks: World Bank, Asian Development Bank and Islamic Development Bank Donor countries development aid institutes: USAID, JICA, UKAID, EU, JFPR
Regional partnerships	South Asian Association for Regional Cooperation (SAARC) South Asia Co-operative Environment Programme (SACEP)

Non-Government Organizations (NGOs) (Working at National Level)	Parley Maldives, Eco Care, Blue Peace Maldives, Live and learn Environmental Education, Blue Marine foundation, WaterCare, Save the Beach, Land Sea Maldives, Small Islands Geographic Society, Zerowaste, Endeavor, Island Development and Environmental Awareness Society, Maldives Authentic Crafts Society, Beleaf, Maldives Underwater Initiative by Six Senses Laamu, Soneva Namoona Baa and The Asia Foundation.
Education and Research	The Maldives National University (MNU) The Maldives Marine Resource Institute (MMRI) Maldives Climate Observatory, HDh. Hanimaadhoo (MCOH)
State Owned and Public -Private Enterprises	Male' Water & Sewerage Company Pvt. Ltd. (MWSC) State Electric Company Ltd. (STELCO) Waste Management Corporation Ltd. (WAMCO) Fenaka Corporation Ltd. AgroNational Cooperation (AgroNat) State Trading Organization (STO)
Private Sector	Maldives Energy and Environment Company CDE Consulting Water solutions Pvt Ltd Land and Marine Environmental Resource Riyan Pvt Ltd Wholesale & Retail Businesses Tourist Resorts
Others	Women's Development Committees Island based NGO's and CBO's. Farmers/gardeners/poulters/goat herders/women Mainstream media Transparency Maldives Climate Action Network South Asia

Core authorities, ministries and institutions relevant to N_r directly include:

- Ministry of Environment, Climate Change and Technology (Departments: Climate Change, Environment Management and Conservation, Energy, Waste Management & Pollution Control, Water & Sanitation)
- Ministry of Fisheries, Marine Resources and Agriculture
- Ministry of Tourism
- Ministry of Health
- Environmental Protection Agency
- Maldives Meteorological Services
- National Disaster Management Authority
- Utility Regulatory Authority
- Local Councils

Ministries and government authorities that may also be relevant to N_r, but indirectly, include those responsible for finance, education, and other social and cultural services. The preliminary list of ministries that may also influence N_r management and policy include:

- Ministry of Economic Development
- Ministry of Finance
- Ministry of National Planning, Housing and Infrastructure
- Ministry of Defence and National Security
- Ministry of Education
- Ministry of Higher Education
- Ministry of Gender and Family
- Ministry of Information Technology
- National Bureau of Statistics

Coordinating and Decision-making Committees

- Parliament Members
- President's Cabinet

SANH aims to conduct a stakeholder analysis for Maldives in order to highlight the range of government and non-government groups who have interest/ influence on a specific nitrogen relevant policy intervention in the country in order to aid future decision making and enhance integrated (intra and inter-sectoral) dialogues and inclusivity to support a consensus-building policy process.

9. Recommendations and Future Outlook

In summary, this report has been able to bring together the evidence on nitrogen emission trends and sources, current interventions, the policy landscape and relevant literature for the Maldives. Lessons based on the evidence provided have been identified along with recommendations to support and strengthen the development of nitrogen related policies. In addition, examples of policy action already taken in Maldives that have promising potential to reduce N_r waste are also highlighted.

9.1 Key policy considerations include:

- Some policies indicate favourable features (multiple sinks and sectors and policy instruments) and a desirable direction for future policy. More integrated policies and integration across policies would be crucial to address nitrogen issues systematically.
- Nitrogen policies should be informed by data and evidence and the associated action plans should require research, evaluation of N_r emissions to monitor and mitigate actions. Increasing the number of relevant policies for research and development would be recommended across the range of sectors.
- Nitrogen oxide (NO_x) emissions were identified as 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.
- A fairly high proportion of core policies were classified as regulatory – policies such as those defining water and air N_r related standards should be complemented by a broader integrated policy framework.
- Currently, focus is on GHG emissions but monitoring of air pollutants and water quality in more heavily populated regions would be beneficial to understanding localised N_r trends and the impacts.
- Priority sectors for action in Maldives to reduce N_r waste/pollution include transport sector (including road, marine transport and the aviation sector), waste & wastewater management, and energy.
- Transport, a key sector in terms of N_r management, it is important in Maldives to ensure the implementation of the National Action Plan on Air Pollutants (2019) and move towards environmentally friendly modes of transport.
- Agriculture N_r emissions based on EDGAR data show a decreasing trend. However, import data of organic and inorganic fertilizer to the country is showing an increasing trend. Thus, agricultural N_r emission and agricultural fertiliser practices, need further attention to address this knowledge gap.
- Urban development projects (Thila-Malé Bridge development connecting Malé with the adjoining islands of Villingli, Gulhifalhu and Thilafushi.) will provide ease of travelling between islands. However, it would lead to increasing transport emission rates in the Greater Malé Area[144].
- Studies conducted on environmental pollution including urban air pollution are limited and there is a crucial need to establish a long-term monitoring program.
- There is limited information and data available on the effects of environmental pollution on the environment and human health. Research studies conducted globally indicate significant relationship between environmental pollution and adverse health effects[145]. It would be crucial to establish research programs to assess N pollution and the effects of it on the environment and human health. The Ministries in collaboration with the research institutions could institutionalize research programs.

[144] SASEC. (2021). Maldives and India Undertake the Greater Malé Connectivity Project. Retrieved 25 April 2022, from https://www.sasec.asia/index.php?page=news&nid=1308&url=greater-Malé-connectivity

[145] MEE (2017) State of the Environment 2016, Ministry of Environment and Energy

9.2 Solutions from sectors

- MoECCT in affiliation with EPA, acts as the lead entity to develop and enforce regulations to ensure environmental management including pollution prevention under the Environment Protection and Preservation Act (4/93). The MoECCT can act as a mediator in the nitrogen policy and regulatory frameworks development. Multi-stakeholder inputs will be required to develop an inclusive policy and plan to instigate change.

- The national action plan on air pollutants 'roadmap for air quality and management for Maldives' has been developed by the MoECCT. The plan sets targets to reduce greenhouse gas (GHG) emissions by 2030 compared to a 'business as usual' scenario. These targets could be increased to going net zero in a conditional manner, contingent on the availability of financial resources. The target is to reduce nitrogen oxides by approximately 27% [146].

- The Air Quality Monitoring programme is under commencement through the deployment of low-cost air quality monitoring sensors by MoECCT across the Maldives[147].

- The Maldives National University (MNU) is working with assistance from the Duke University (USA) on a research project on Air Quality Monitoring. A sensor network has been established with 6 TSI Blue sky air quality sensors to monitor $PM_{2.5}$ levels in the Greater Male' region. In addition, a new resolution on sustainable nitrogen management was also adopted, encouraging the development of national action plans for sustainable nitrogen management. This will include, amongst other actions, possible modalities of options for improved coordination, intergovernmental coordination mechanism and development of a road map leading up to 6th UNEA.

- Maldives has the ability to strengthen regional and international commitments such as support of UNEA-5.2 and preparing for UNEA-6 to manage nitrogen sustainably.

- The Maldives Climate Observatory (MCOH), located in Haa Dhaalu Hanimaadhoo was set up in 2004 as an observatory for research on air pollution, climate and radiation[148]. The MCOH measures and monitors the transboundary air pollution and the atmospheric composition over the Indian Ocean and acts as a receptor site for long range transport of pollutants from the regions of South Asia, Middle East and Africa. The MCOH measures black carbon, key gas species such as ozone and carbon monoxide, and aerosol properties. One key target of MCOH is to monitor how anthropogenic activities in the region are modifying air quality and climate.

- The National Fisheries and Agricultural Policy 2019-2029 and associated plans may have an impact on N emissions[149].

- The Strategic Action Plan (2019 – 2023) by the Government outlines development targets, priorities and strategic actions to promote environmental protection, conservation and to reduce pollution. The plan specifically mentions targets to reduce carbon emission, however, nitrogen management is not addressed.

SANH along with SACEP will continue to support South Asia countries in developing guidelines for a general policy framework for nitrogen-relevant policy interventions, develop national nitrogen budgets and future visions and scenarios, and improving understanding and awareness of key nitrogen threats, amongst other actions.

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[146] Ministry of Environment. (2019). National Action Plan for Air pollution, determining nationally avoid emissions; retrieved from: https://www.environment.gov.mv/v2/en/download/9444

[147] The Times of Addu. (2022). Regional Air Quality Monitoring Project launches with sensor installation in Addu City. Retrieved from https://timesofaddu.com/2022/02/21/regional-air-quality-monitoring-project-launches-with-sensor-installation-in-addu-city/

[148] In collaboration with the Maldives Meteorological Services, MCOH science team and UN Environment.

[149] Ministry of Fisheries, Marine Resources and Agriculture of the Republic of Maldives and FAO, (2021). National Fisheries and Agricultural Policy 2019-2029. [online] Gov.mv. Available at: <https://www.gov.mv/dv/files/national-fisheries-and-agricultural-policy-2019-2029.pdf> [Accessed 8 November 2021].

References

Ahusan, M., Adam, M. S., Ziyad, A., Shifaz, A., Shimal, M., & Jauharee, R. (2018). *Maldives National Report Submitted to The Indian Ocean Tuna Commission Scientific Committee - 2018.* IOTC. Retrieved February 10, 2022, from https://www.iotc.org/documents/SC/21/NR16

Asian Development Bank. (2021). *Maldives Economic Update 2020.* Asian Development Bank. Retrieved from https://www.adb.org/sites/default/files/institutional-document/674971/maldives-economic-update-2020.pdf

Bansal, S., Raghuram, N., Adhya, T., Rahman, M., Tshering, D., & Dahal, K. et al. (2022). *Long-term trends of direct nitrous oxide emission from fuel combustion in South Asia.* Retrieved 25 April 2022, from https://iopscience.iop.org/article/10.1088/1748-9326/ac5cf7

Bailey, R., Khalil, A., & Chatikavanij, V. (2014). Estimating Current and Future Groundwater Resources of the Maldives. *JAWRA Journal Of The American Water Resources Association, 51*(1), 112-122. doi: 10.1111/jawr.12236

Climate and Clean Air Coalition. (2021). Maldives, Republic of the. Retrieved 28 November 2021, from https://www.ccacoalition.org/en/partners/maldives-republic

Zhongming, Z., Linong, L., Xiaona, Y., Wangqiang, Z., & Wei, L. (2021). Climate Risk Country Profile: Maldives.

Commerce, Development and Environment Pvt. Ltd. (2007). *EIA for the Proposed Agricultural Investment in Hdh. Keylakunu.* Retrieved from http://saruna.mnu.edu.mv/jspui/bitstream/123456789/7488/1/Environment%20Impact%20Assessment%20for%20proposed%20agricultural%20Development%20in%20Keylakunu%2C%20Haa%20Dhaalu%20Atoll.pdf

Commerce, Development and Environment Pvt. Ltd. (2007). *Environmental Impact Assessment for Proposed Agricultural Establishment.* Male': Commerce, Development and Environment Pvt. Ltd. Retrieved from: http://saruna.mnu.edu.mv/jspui/bitstream/123456789/7488/1/Environment%20Impact%20Assessment%20for%20proposed%20agricultural%20Development%20in%20Keylakunu%2C%20Haa%20Dhaalu%20Atoll.pdf

Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Oreggioni, G. (2019a). EDGAR v5.0 Global Air Pollutant Emissions. European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/377801af-b094-4943-8fdc-f79a7c0c2d19

Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Lo Vullo, E., Solazzo, E., Monforti-Ferrario, F., Olivier, J.G.J., Vignati, E.E. (2019b). EDGAR v5.0 Greenhouse Gas Emissions. European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/488dc3de-f072-4810-ab83-47185158ce2a

EDGAR Database: https://edgar.jrc.ec.europa.eu/ 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

Erisman, J.W., Galloway, J.N., Seitzinger, S., Bleeker, A., Dise, N.B., Petrescu, A.R., Leach, A.M. and de Vries, W. (2013). Consequences of human modification of the global nitrogen cycle. Philosophical Transactions of the Royal Society B: Biological Sciences, 368(1621): 20130116.

European Space Agency. (2019). Copernicus Open Access Hub. Available online: https://scihub.copernicus.eu/

Fallati, L., Savini, A., Sterlacchini, S. et al. Land use and land cover (LULC) of the Republic of the Maldives: first national map and LULC change analysis using remote-sensing data. *Environ Monit Assess* 189, 417 (2017). https://doi.org/10.1007/s10661-017-6120-2

FAO, 2016. *Peace Conflict and Food Security What do we know about the linkages?* Technical Note. [online] Reliefweb.int. Available at: <https://reliefweb.int/sites/reliefweb.int/files/resources/a-i5521e_0.pdf> [Accessed 14 November 2021].

FAO. (2018). *Impacts of climate change on fisheries and aquaculture Synthesis of current knowledge, adaptation and mitigation options.* Retrieved 22 May 2022, from https://www.fao.org/3/i9705en/i9705en.pdf

FAO. (2004). *Review of the state of world marine capture fisheries management: Indian Ocean.* Retrieved 3 October 2021, from http://www.fao.org/3/a0477e/a0477e0y.htm#:~:text=Maldives%20is%20an%20archipelago%20of,nearly%20one%20million%20km2.

FAO. (2007). *The Maldives: Introduction.* Retrieved February 07, 2022, from https://www.fao.org/3/ai387e/AI387E03.htm

FAO. (2022). *Country Programming Framework for the Republic of Maldives 2022±2026.* Male'. https://doi.org/10.4060/cb9288en

IATA. (2018). *The Importance of Air Transport to the Maldives.* Retrieved 14 February 2022, from https://www.iata.org/en/iata-repository/publications/economic-reports/maldives--value-of-aviation/#:~:text=The%20air%20transport%20industry%2C%20including,GDP%2C%20totaling%20US%20%243.1%20billion.

Invest Maldives. (2022). *Information Communications and Technology - Invest Maldives.* Retrieved 14 February 2022, from https://investmaldives.gov.mv/Opportunities/Ict

IRENA. (2021). *Energy Profile: Maldives.* Retrieved 13 March 2022, from https://www.irena.org/IRENADocuments/Statistical_Profiles/Asia/Maldives_Asia_RE_SP.pdf

Islam, F., Lian, Q., Ahmad, Z. U., Zappi, M. E., Yao, L., & Gang, D. D. (2018). Nonpoint source pollution. *Water Environment Research, 90*(10), 1872–1898. https://doi.org/10.2175/106143017x15131012188033

ITU. (2011). *The Role of ICT in Advancing Growth in Least Developed Countries - Trends, Challenges and Opportunities.* Retrieved 14 February 2022, from https://www.itu.int/pub/D-LDC-ICTLDC.2011-2011

Jauharee, A. R., Neal, K. and Miller, K. I. (2015). Maldives tuna Pole-and-line Tuna Fishery: *Livebait Fishery Review*, MRC, IPNLF and MSPEA, December 2015. 60 pages.

KindPng. (2021). World Map Minimalist, HD Png Download [Image]. Retrieved from https://www.kindpng.com/picc/m/30-307661_world-map-minimalist-hd-png-download.png

Maldives Customs Service. (2022). *Customs Statistics.* Retrieved 1 March 2022, from https://www.customs.gov.mv/Statistics

MNU. (2022). The Maldives National University Presented at the Fifth Session of the United Nations Environment Assembly. Retrieved 13 April 2022, from https://mnu.edu.mv/the-maldives-national-university-presented-at-the-fifth-session-of-the-united-nations-environment-assembly/

MEE, (2015). *Fifth National Report of Maldives to the Convention on Biological Diversity.* Maldives: Ministry of Environment and Energy

MEE. (2016). *Maldives National Chemical Profile 2015*, Ministry of Environment and Energy

MEE. (2017). *State of the Environment 2016,* Ministry of Environment and Energy

ME, (2019), *Maldives First Biennial Update Report to the United Nations Framework Convention on Climate Change,* Maldives: Ministry of Environment

Ministry of Environment. (2019). *National Action Plan on Air Pollutants: Determining Nationally Avoided Emissions.* Malé: Ministry of Environment. Retrieved from https://www.ccacoalition.org/en/resources/maldives-national-action-plan-air-pollutants.

Ministry of Fisheries and Agriculture. (2021). Maldives. Retrieved 5 October 2021, from https://www.atollsofmaldives.gov.mv/atolls

Ministry of Fisheries and Agriculture. (2021). Maldives. Retrieved 10 October 2021, from https://www atollsofmaldives.gov.mv/atolls/Ari-Atholhu-Uthuruburi-(Alifu-Alifu-Atoll)

Ministry of Fisheries, Marine Resources and Agriculture of the Republic of Maldives and FAO, (2021). *National Fisheries and Agricultural Policy 2019-2029.* [online] Gov.mv. Available at: <https://www.gov.mv/dv/files/

national-fisheries-and-agricultural-policy-2019-2029.pdf> [Accessed 8 November 2021].

Ministry of National Planning, Housing & Infrastructure. (2020). *Land use plan* | MNPHI – Ministry of National Planning, Housing & Infrastructure. Retrieved 10 October 2021, from https://planning.gov.mv/planning

National Bureau of Statistics. (2019). *Employment in Tourist Resorts*, 2019. Retrieved 22 November 2021, from http://statisticsmaldives.gov.mv/nbs/wp-content/uploads/2020/06/Resort-Employee-Survey-2019-1.pdf

National Bureau of Statistics. (2020). *Statistical Pocketbook of Maldives 2020.* 2020. Retrieved 3 October 2021, from http://statisticsmaldives.gov.mv/nbs/wp-content/uploads/2020/10/Statistical-Pocketbook-2020.pdf

NOAA. (2022). *Impacts of el Niño on fish distribution.* El Nino Theme Page - Pacific Marine Environmental Laboratory. Retrieved February 9, 2022, from https://www.pmel.noaa.gov/elnino/fish-distribution

Permanent Mission of the Republic of Maldives to the United Nations. (2018). AOSIS Chairmanship. Retrieved 28 November 2021, from http://maldivesmission.com/campaign/aosis_chairmanship

Rashfa, M. (2014). A Review of the Maldivian Construction Industry - *Research and Policy Notes* JUNE 2014 RPN 4-14. Maldives Monetary Authority. Retrieved January 2022, from http://www.mma.gov.mv/documents/Research%20and%20Policy%20Notes/2014/A%20Review%20of%20the%20Maldivian%20Construction%20Industry.pdf

SACEP. (2001). *Environmental Legislation and Institutions in the Maldives.* Retrieved 18 November 2021, from http://www.sacep.org/pdf/Reports-Technical/2001-UNEP-SACEP-Law-Handbook%20-Maldives.pdf

SACEP & SANH (2021) *South Asian Regional Cooperation on Sustainable Nitrogen Management, Nitrogen Pollution in South Asia: Scientific Evidence, Current Initiatives and Policy Landscape*, SANH Policy Paper PP1, Colombo & Edinburgh.

The World Bank. (2018). *Agricultural land (% of land area) - South Asia* | Data. Retrieved 24 October 2021, from https://data.worldbank.org/indicator/AG.LND.AGRI.ZS?locations=8S

The World Bank. (2020). *Industry (including construction), value added (constant 2015 US$) - Maldives.* Retrieved January 27, 2022, from https://data.worldbank.org/indicator/NV.IND.TOTL.KD?locations=MV

The World Bank. (2021). *Arable land (% of land area) - Maldives* | Data. Retrieved 5 August 2021, from https://data.worldbank.org/indicator/AG.LND.ARBL.ZS?locations=MV0

The World Bank. (2021). *World Development Indicators,* The World Bank. Retrieved 24 October 2021, from http://wdi.worldbank.org/table/4.2

The World Bank. (2022). *The World Bank in Maldives: Overview.* Retrieved 19 April 2022, from https://www.worldbank.org/en/country/maldives/overview#1

UN. (2010). *Commission on the Limits of the Continental Shelf*: Submission by the Republic of Maldives. Retrieved 6 October 2021, from https://www.un.org/depts/los/clcs_new/submissions_files/mdv53_10/MAL-ES-DOC.pdf

UNEP. (2019). *Frontiers 2018/19: Emerging Issues of Environmental Concern.* Nairobi: United Nations Environment Programme.

WHO. (2021). WHO 2021 Air Quality Guidelines [2005 & 2021]. Retrieved June, 2022, from https://seetheair.files.wordpress.com/2021/09/who-seetheair-aqgs-1.jpg?w=512

Xu, R., Tian, H., Pan, S., Prior, S.A., Feng, Y., Batchelor, W.D., Chen, J. and Yang, J. (2019). Global ammonia emissions from synthetic nitrogen fertilizer applications in agricultural systems: Empirical and process-based estimates and uncertainty. *Global Change Biology,* 25 (1):314-326

Yang, A. L., Adhya, T. K., Anik, A. R., Bansal, S., Das, S., Hassan, R., … Watto, M. A. (2021). Nitrogen-relevant policies from South Asia collected by the South Asian Nitrogen Hub (SANH) 2020-2021 [Data set]. NERC EDS Environmental Information Data Centre. https://doi.org/10.5285/E2F248D5-79A1-4AF9-BDD4-F739FB12CE9A

Appendix

Table 28: distribution of islands by administrative atolls (Source: Ministry of Environment and Energy, 2015)

#	Administrative Atolls	Atoll Code
1	North Thiladhunmathi	Haa Alifu
2	South Thiladhunmathi	Haa Dhaalu
3	North Miladhunmadulu	Shaviyani
4	South Miladhunmadulu	Noonu
5	North Maalhosmadulu	Raa
6	South Maalhosmadulu	Baa
7	Faadhippolhu	Lhaviyani
8	Male' Atoll	Kaafu
9	North Ari Atoll	Alifu Alifu
10	South Ari Atoll	Alifu Dhaalu
11	Felidhe Atoll	Vaavu
12	Mulaku Atoll	Meemu
13	North Nilandhe Atoll	Faafu
14	South Nilandhe Atoll	Dhaalu
15	Kolhumadulu	Thaa
16	Hadhdhunmathi	Laamu
17	North Huvadhoo Atoll	Gaafu Alifu Atoll
18	South Huvadhoo Atoll	Gaafu Dhaalu
19	Fuvammulah	Gnaviyani
20	Addu Atoll	Seenu

Table 29: Import quantity vs price for inorganic & organic fertilizer, cow dung and urea into Maldives from 2010-2019 (Source: Maldives Customs Services, 2022) (refer figure 26)

	Inorganic Fertilizer	Price in MVR	Organic Fertilizer	Price in MVR	Cow Dung	Price in MVR	Urea	Price in MVR
2010	778,977	3,646,159	1,508,873	2,563,420	6,880,074	5,631,415	17,250	106,472
2011	932,263	5,522,571	1,626,875	4,054,721	7,633,512	7,223,469	26,680	210,162
2012	1,378,038	7,600,071	1,448,716	2,982,005	8,581,162	9,011,011	37,920	255,274
2013	898,946	7,100,776	1,523,654	4,010,514	7,041,809	8,069,904	2,903	15,488
2014	901,489	6,741,660	1,639,971	4,163,605	6,947,533	9,259,151	26,950	139,609
2015	1,025,446	7,399,489	1,419,513	3,786,852	8,723,748	9,132,228	30,563	861,996
2016	1,315,111	9,394,317	1,786,195	4,664,769	9,522,918	10,283,785	25,570	143,932
2017	1,387,876	7,408,678	1,748,982	7,914,288	6,866,413	12,769,590	3,204	28,455
2018	1,915,339	9,892,699	4,263,534	9,774,823	8,767,952	12,028,134	5,965	22,447
2019	967,109	6,521,659	6,021,964	15,570,774	7,776,483	10,420,223	34,110	160,538
Total	11,500,594	71,228,080	22,988,276	59,485,772	78,741,604	93,828,910	211,114	1,944,374

Table 30: Total Imports of fuel 2010 and 2020 (Jan-July) for Maldives (Source: Maldives Customs Services, 2021)

Name of fuel	Quantity (TNE)		% Change
	2010	2020	
Marine Gas Oil (Diesel)	286,900.11	516,108.04	80
Petrol	29,864.96	58,638.73	96

Table 31: WHO 2021 AQG Levels, (Source: WHO, 2021)

Pollutant	Averaging Time	2005 AQGs	2021 AQGs
$PM_{2.5}$ μg/m³	Annual	10	**5** ↓
	24-hour	25	**15** ↓
PM_{10} μg/m³	Annual	20	**15** ↓
	24-hour	50	**45** ↓
O_3 μg/m³	Peak season	-	**60**
	8-hour	100	**100**
NO_2 μg/m³	Annual	40	**10** ↓
	24-hour	-	**25**
SO_2 μg/m³	24-hour	20	**40** ↑
CO mg/m³	24-hour	-	**4**

Table 32 : SANH Nitrogen - relevant policy classification lists

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, categorizing as a main sector was sufficient.

Policy type. (Policies could include multiple policy instruments, therefore policies could be coded under one or more of these codes as appropriate.)	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.
	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, i.e. 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 cover 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). 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 recognize 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 fertilizer 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. 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 word were used to identify policies, i.e., if the policy contained one or more of these listed key words [128] .
	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 NOx emissions, unless mitigated by other policy initiatives and measures.

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

Table 33: List of Policies assessed by SANH

#	Date
National Action Plan on Air Pollutants.	2019
Strategic Action Plan (SAP) 2019 - 2023.	2019
Fisheries Act of the Maldives (No. 14/2019).	2019
EIA data collection guideline	2019
Building Code	2019
Supply water quality standard	2018
Environmental and Social Management Plan – Island Waste Management Center in Lh. Kurendhoo	2018
National Water and Sewerage Policy.	2017
National Action Plan for Containment of Antimicrobial Resistance 2017-2022.	2017
National Food Safety Policy (2017-2026)	2017
National Healthcare Waste Management Strategic Plan.	2017
National Awareness Strategy for Water and Sewerage.	2017
Environmental Guidelines for site selection of Waste Management Centers	2017
Construction Act	2017
Maldives Clean Environment Project Environmental and Social Assessment and Management Framework (ESAMF) and Resettlement Policy Framework (RPF)	2016
Maldives Energy Policy and Strategy 2016	2016
Environmental Guidelines for Concrete Batching Plants	2016
Maldives Health Master Plan 2016 -2025	2016
National Biodiversity Strategy and Action Plan 2016-2025.	2015
Maldives' Intended Nationally Determined Contribution (INDC).	2015
Climate Change Policy Framework (2015-2025)	2015
National Waste Management Policy 2015	2015
Business Registation Act (Law No. 18-2014)	2014
Sole Proprietorship Act	2014
Waste Management Regulation (No. 2013/R-58) (4 x amendments 2014, 2017, 2018)	2013
Small and Medium Enterprises Act	2013
Regulation on the Preparation of Environmental Impact Assessment Report 2012 (No. 2012/R-27)	2012
Maldives National Energy Policy and Strategy 2010	2010
Third National Environment Action Plan (NEAP III)	2009
National Solid Waste Management Policy	2008
National Waste Water Quality Guidelines	2007
Design Criteria and Technical Specification for Conventional Gravity Sewerage Systems	2007
Environmental Impact Assessment Regulations, 2007 (5 amendments)	2007
Seventh National Development Plan.	2006
Regulation on the Protection and Conservation of Environment in the Tourism Industry.	2006
Strategic Economic Plan (SEP).	2005
Drainage and Plumbing Regulations 1996.	1996
Sewage Disposal Regulations 1996.	1996
The Companies Act of Maldives	1996
Environment Protection and Preservation Act of Maldives (Amended: 2014)	1993

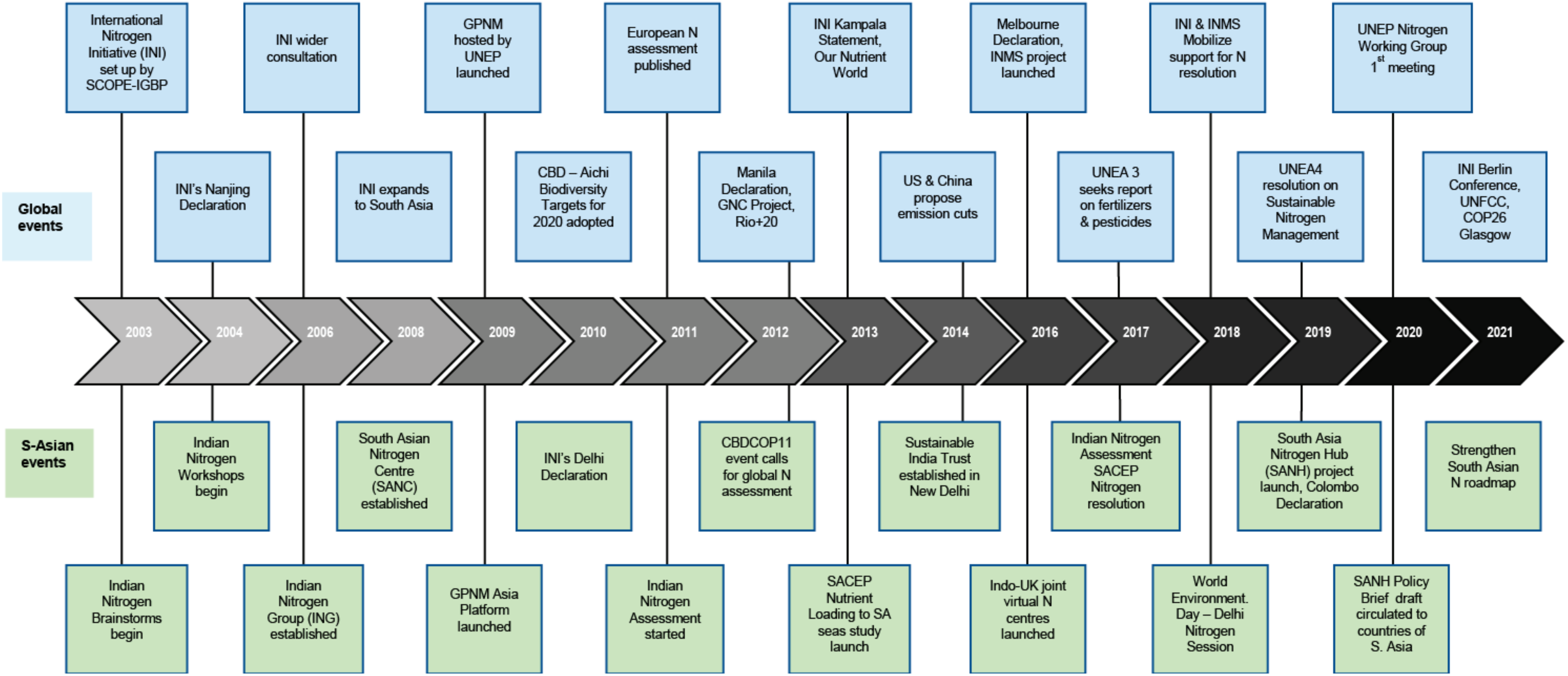

Figure 7: Timeline of global and South Asian developments toward global cooperation on sustainable nitrogen management

Source: Raghuram et al. (2021) [38]

The Maldives National University (MNU) | South Asian Nitrogen Hub (SANH)

THE MALDIVES NATIONAL UNIVERSITY

UK Research and Innovation

GCRF Global Challenges Research Fund

Nitrogen Hub