Nitrogen Policy Report

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National Nitrogen Policy Report:
SRI LANKA

University of Peradeniya
South Asian Nitrogen Hub (SANH)

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Foreword – Message from the SANH Project Scientific Coordinator for Sri Lanka

Nitrogen pollution is one of the main global environmental issues in the 21st century. The nitrogen cycle is affected by industrialization; causing many adverse effects to the environment and the human kind. Despite the fact that nitrogen pollution has a significant negative impact, the global community pays little attention to it. In the future, nitrogen pollution will be one of the most serious risks to life on earth. To address this problem regionally in South Asia, Center for Ecology and Hydrology (CEH) of UK with the support of the UKRI Global Challenge Research Fund (GCRF) had initiated a research hub as South Asian Nitrogen Hub (GCRF- SANH). Thirty two leading research institutions in South Asia and UK had engaged as member organizations of the SANH, and the CEH is coordinating the project. All eight countries of South Asia are members of the SANH.

The main objective of the SANH is to reduce nitrogen losses in the agriculture sector through efficient use of resources such as manure, urea and biological nitrogen fixation processes etc. Also it encourages policy makers to strengthen policies on nitrogen pollution across multiple sectors; investigate the impacts and flows of nitrogen pollution in the region, raise awareness on the nitrogen challenge on the community, and predict future nitrogen states. The SANH has laid its focus on studies under four work packages to achieve the set targets. Regional legislation is analysed in the work package (WP) 1 to map existing regulations related to nitrogen use and impacts in member countries. This report was prepared as an outcome of the analysis of the country policy status in regulating nitrogen use and pollution control in Sri Lanka.

Out of 32 leading institutions involved in the project, University of Peradeniya is the main institution of Sri Lanka conducting research and supporting decision makers on the nitrogen status of the country. University of Peradeniya contributes to the project by actively involving in the WP 1 (building the nitrogen pollution arena), WP 2 (nitrogen solutions to maximize resilience, co-benefits and reduce trade-offs), and WP 3 (improving understanding and awareness of key nitrogen threats).

Several global initiations have been proposed to control and minimize the effect of nitrogen pollution. Following the Colombo declaration, a notable initiative as stated above, member countries have pledged to halve their nitrogen pollution by 2030. Therefore, an ample concern has initiated on this problem at the country level, but the extents of the importance of these actions have not been properly penetrated to the community.

Being a project dedicated to finding solutions through increasing awareness, building capacities and formulating regulations for sustainable nitrogen management, it is essential to study the present status of the policy level interventions to support policy makers to amend existing and/or to develop new policies to regulate nitrogen pollution. This is the first comprehensive study conducted to analyse the existing policy environment in Sri Lanka related to Nitrogen use and management. We sincerely believe that this report will be a useful resource providing insights to the Sri Lankan decision makers to design an effective policy framework to control nitrogen pollution and mitigate its negative effects on environment and human health.

Prof. N.A.A.S.P. Nissanka/ SANH Project Scientific Coordinator for Sri Lanka

Peradeniya, June, 2022

Foreword - Message from the Director of South Asian Nitrogen Hub

This report, prepared by the University of Peradeniya in partnership with the UKRI GCRF South Asian Nitrogen Hub (SANH), without doubt represents a milestone in international cooperation on sustainable nitrogen management. The foundation of the Hub is closely linked to South Asia Co-operative Environment Programme (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 led by India. Agreement to cooperate in a competitive proposal to UKRI ultimately established the GCRF SANH.

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.

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'. This is the first time that such a reduction intent for nitrogen waste has been agreed universally by the UN, and it is therefore a major step forward to the UN Sustainable Development Goals (SDGs). The information and the lessons from the present report are therefore very timely in providing support to turn this ambition into reality.

Prof Mark Sutton

Director UKRI GCRF South Asian Nitrogen Hub

Edinburgh, June, 2022

Executive Summary

Nitrogen is essential for life, but nitrogen in its reactive form (N_r) in excess can causes 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) x 300 more warming potential than CO_2. South Asia is a global hotspot for N_r emissions for the main nitrogen compounds: nitrogen oxide, nitrous oxide and ammonia, 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 national levels 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.

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. This database includes 115 nitrogen related policies collected from Sri Lanka. Drawing on that database, this SANH national report outlines the implications of these findings for Sri Lanka. This country report is the first of its kind to provide a national overview on the extent of nitrogen-related policies for Sri Lanka.

The results of the policy analysis depict that the recent Sri Lankan governments have taken a number of positive policy initiatives to curb N_r pollution caused by the agriculture, industrial, waste, land use, energy and transport sectors in Sri Lanka. However, data shows that emissions from all three nitrogen compounds, ammonia (NH_3), nitrogen oxides (NO_x), and nitrous oxide (N_2O), have been increasing over time in Sri Lanka and elsewhere in South Asia. These results highlight that current policy efforts so far have not yet been able to stabilise or reduce N_r emissions. The report highlights the issues and challenges around nitrogen pollution and management, with recommendations for action.

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1 Introduction

1.1 Lead institution and SANH

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

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

SANH research programmes focus on the following four key areas:

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

1.2 What is the purpose of this report?

This report is part of SANH actions towards building the nitrogen policy arena for South Asia. It is specifically focused on the evaluation of current policies, progress and barriers across different scales within each of the eight countries. Our approach firstly looked at the regional scale[1] and now aims to focus on the national scale.

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

This report provides a necessary step to understanding the current nitrogen policy landscape for Sri Lanka within South Asia. National level reports of this kind are being prepared for each of the eight SACEP member countries.

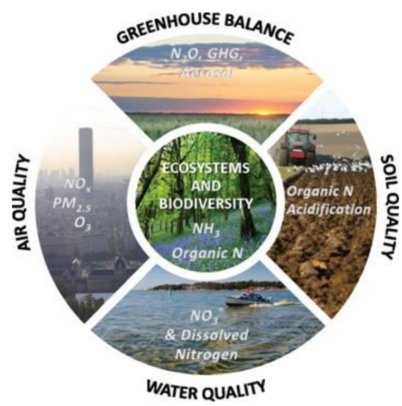
The report is structured in the following way:

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

1.3 Why focus on nitrogen pollution?

Utilising nitrogen, in its reactive form (N_r), has been essential for human development. Nitrogen has been altered in order to produce chemicals, fertilisers, and other useful products (European Commission, 2013). Agriculture depends on nitrogen, with fertilisers, 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 production has more than doubled during the last century as a result of human activity" (Sutton et al., 2009).

Figure 1. Threats from nitrogen pollution,
Source: Sutton and Billen, 2010



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+) (European Commission, 2013).

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).

Reductions in 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 (UNFCC, 2021). 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 (Robertson et al. 2013).

1.4 How does reactive nitrogen (N_r) impact the environment and human health?

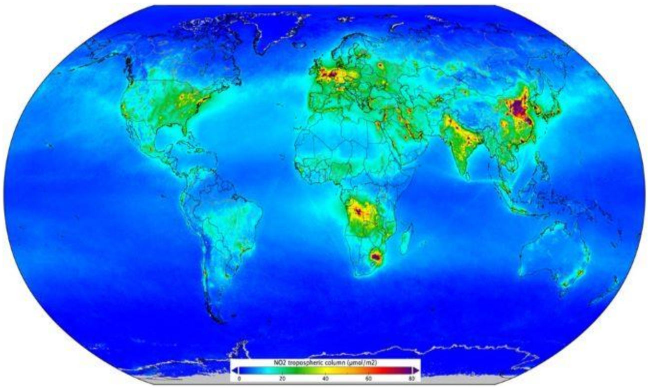
Nitrogen pollution threatens the environment in multiple ways with knock on effects for society. For example, the combined cost to ecosystems, climate and health was estimated at over €70 billion per year to the EU alone (Brink et al., 2011). Most of these costs were attributed to the impacts on human 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 (Kegl, 2007).

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 (United States Environmental Protection Agency, 2019). PM concentrations are argued to be higher in areas of growing populations undergoing fast urbanization and industrialization (Ji et al., 2018).

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.



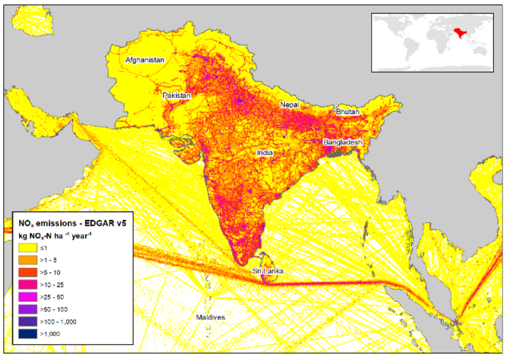


Figure 3. NO_x (nitrogen oxide) emissions across South Asia, 2015,

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

N_r can enter surface water and groundwater as a consequence of agricultural activity and the excess application of synthetic fertilizers and manures (WHO, 2011). 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 ground water pollution (European Commission, 2013). Agricultural activities reportedly account for approximately 80%–90% of the overall anthropogenic ammonia emissions (Bouwman et al., 1997; Zhang et al., 2010)

Ammonia is considered to be more harmful to ecosystems than nitrogen oxides (NO_x) especially when deposited in its dry form (Hicks et al., 2011). South Asia is a global hotspot for ammonia emissions, indicated in Figure 4. The extent of ammonia emissions in South Asia are illustrated in further detail in Figure 5.

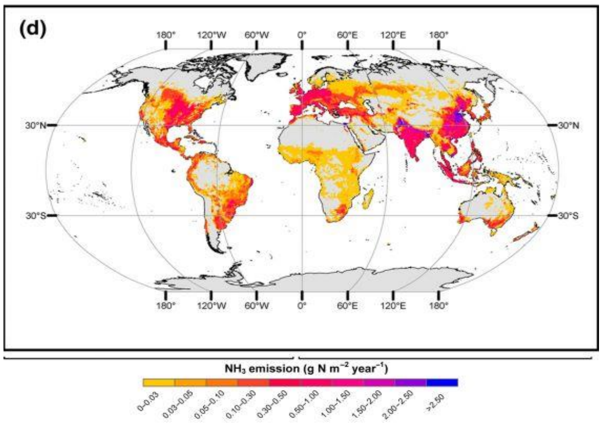


Figure 4. Global map of NH_3- (ammonia) emissions,

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.

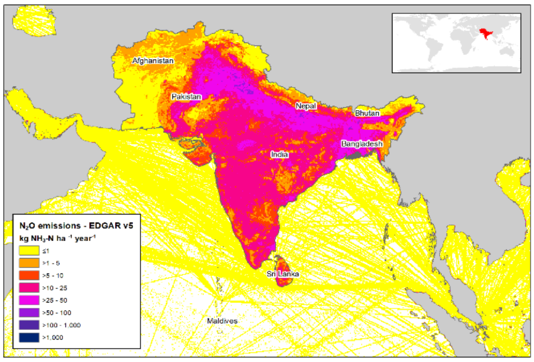
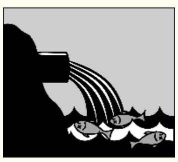


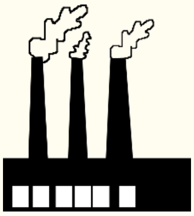
Figure 5. NH_3- (ammonia) emissions across South Asia, 2015,

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

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 Nr emission sources and impacts, and unique differences.

Table 1. Overview of reactive nitrogen emissions and related environmental and health impacts
Source: adapted from Erisman et al. (2013) and UNEP (2019)

Emission	Source	Benefit	Environmental and Health impacts
Nitrate (NO_3) 	Wastewater, agriculture and oxidation of NOx.	Widely used in fertilizer and explosives.	NO_3forms 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	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

(nitrogen oxides) 			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_3causes 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 propellants 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).

Provisioning, regulating, supporting and cultural ecosystem services[2] can be directly and indirectly affected by N_r. 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 Image 1.

Image 1.Fish in an intensive monoculture pond in an eastern Bangladesh wetland.
Source: Arju (2019) The Third Pole

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'* (Erisman et al. 2013).

Whilst local sources of nitrogen pollution, such as air emissions and run off, contribute to local effects, they also can contribute to accumulations at subnational to global scales (Erisman et al. 2013).

[2]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)

Nitrogen pollution does not respect country boundaries. Therefore, tackling nitrogen pollution requires trans-national cooperation.

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

1.5 How can policy support sustainable nitrogen management?

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

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

1) *Command and control (C&C)* i.e. the classic regulation type, where an action or pollution practice is forbidden by law, controlled by the authorities, and fined if in violation.
2) *Market-based regulation and governmental expenditure (MBR)*, for example, when the management of pollution behaviour is regulated via market incentives, typically via a green tax (e.g. N-taxation) under the ‘polluter pays’ principle (Carter 2007) or when funds are provided to promote environmentally friendly behaviour.
3) *Information and voluntary action (IVA);* the promotion of sustainable N-management practices via knowledge production, communication, technologies as well as research and extension services. These actions may also be subsidised or funded by government(s).

Another 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 (Connor et al. 2011; FAO 2017).

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 (Kanter et al 2020b). 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 (Kanter et al. 2020b). One approach that takes this into account is ‘the nitrogen circular economy’. This was adopted by the EU in 2015, aiming to maximise resource efficiency at all steps along the value chain (UNEP, 2019).

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

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."

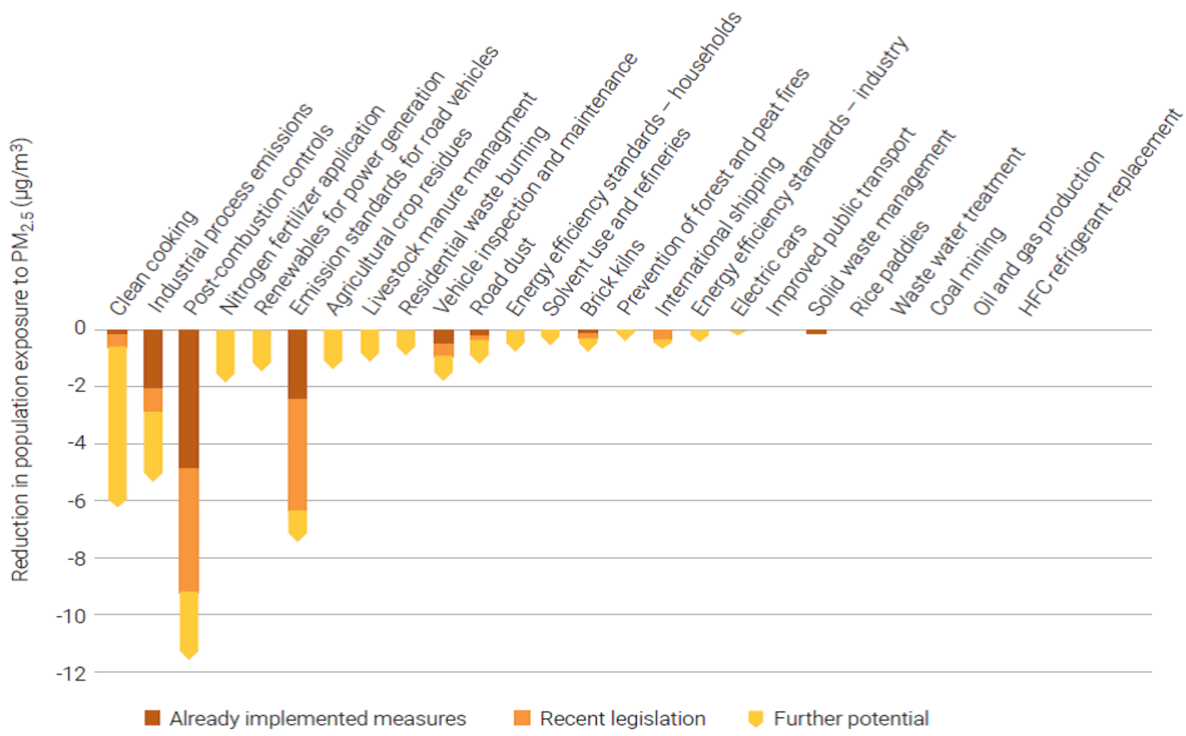
Addressing NUE could provide a 'win-win scenario,' argues Sutton et al. (2009). Studies have shown it could be both environmentally and financially beneficial. Improving NUE is focused on minimising damaging emissions of nitrogen whilst maximising the benefits gained (European Commission, 2013).

Improvements to NUE require changes to agricultural practices. Scientists argue that sustainable agriculture practices, especially those closer to the natural systems, are a way forward. Such practices can include "minimal tillage, intercropping, cover crops, catch crops, green manures (including legumes), animal manures, broad crop rotation, effective use of crop residues, and landscape planning" to reduce N_r waste and increase NUE (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.

Figure 6 gives some examples of other measures that can promote clean air practices to reduce PM pollution. These are 25 'most effective' measures as listed by the Climate and Clean Air Coalition (CCA). Figure 6 indicates some existing measures, those with recent legislation, and those with further potential being implemented in Asia and the Pacific. Post-combustion controls, clean cooking, industrial process emissions, along with emission standards for road vehicles are the measures indicated to have the most impact in reducing $PM_{2.5}$.

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. UNEP (2019) advises, in science and policy, a multi-source, multi-sector perspective that will allow synergies and trade-offs to be better understood. In addition, a holistic, integrated and coherent approach is required to address the global challenge of managing nitrogen effectively and efficiently. Moreover 'smart regulation'¸ the use of multiple rather than single policy instruments, and a broader range of regulatory actors, will also produce better regulation outcomes (Gunningham and Sinclair, 1998).

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



1.6 Global and South Asia policy events

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

Several international policy events in relation to nitrogen can be linked to activities in South Asia (Figure 7).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 (Raghuram et al. 2021).In 2012, the South Asian Nitrogen Centre (SANC) was established as one of the six INI centres in the world.

SANC also is part of the Global Partnership on Nutrient Management (GPNM) which forms a partnership of governments, scientists, policy makers, private sector, NGOs and international organisations to respond to the 'nutrient'. 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 Nr 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. Furthermore, a roadmap for policy change was proposed, including in its activities to establish an Inter-convention Nitrogen Coordination Mechanism (INCOM). INCOM would establish coordination mechanisms across related international conventions to promote action on Sustainable Nitrogen Management 2022-2024 to address nitrogen pollution and report to the sixth session of United Nations Environment Assembly (UNEA). In March 2022, at UNEA-5.2 a new resolution on nitrogen management led by Sri Lanoka, was adopted and aims to build the pathway for the second phase of action in UNEA-6. UNEA-5 encourages member states to nominate the focal points and to develop nitrogen National Action Plans.

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.

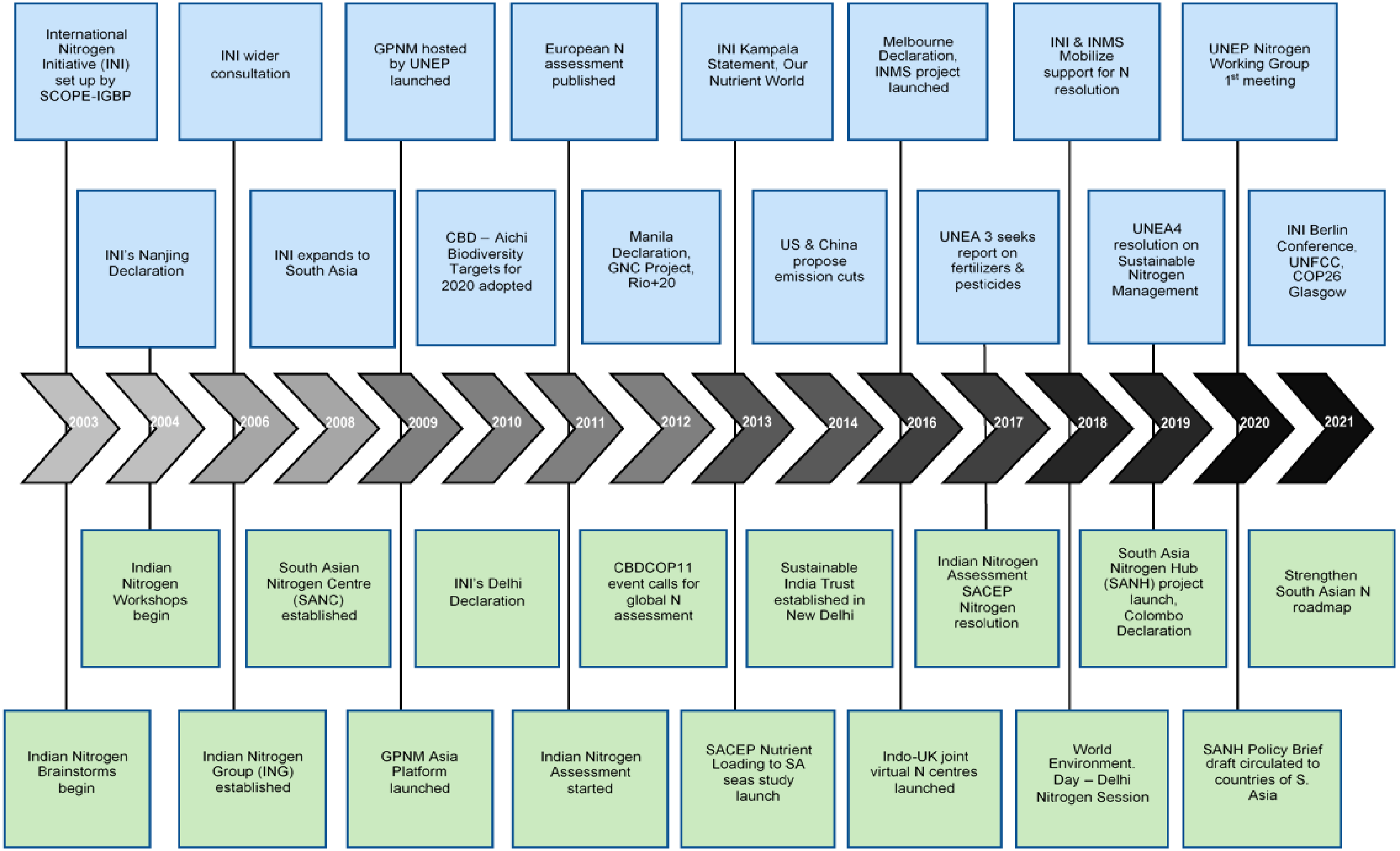
1.7 What do we know about nitrogen policies?

Nitrogen management is a major international policy issue and international policy actions are easier to track. Less is known about the nitrogen policy landscape at national levels (Kanter et al. 2020). A limited understanding remains of how many nitrogen-related policies there are, what issues they address, and what types of instruments are used. In addition, how existing policies may inadvertently lead to increases in nitrogen pollution is also poorly understood.

An initial international assessment attempted to address this knowledge gap by creating the world’s first nitrogen pollution policy database. Kanter et al. (2020) 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. Overall, their analysis revealed that policy integration was limited and ill-equipped to deal with the cross-cutting nature of the global N challenge. Policy fragmentation, and the lack of understanding on nitrogen-related policies and their trade-offs, are barriers to being able to tackle the nitrogen challenge. This is one of the challenges that SANH aims to examine. Investigating the regional and country level implications of the N policy database has yet to be examined for South Asia and is a aim of SANH WP1.1.

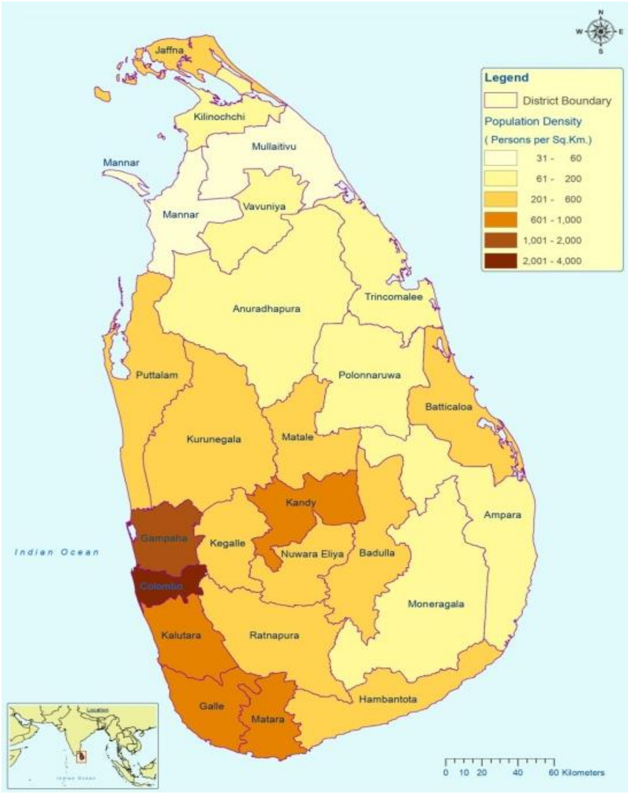
This report is the first of its kind to provide a national overview on the extent of nitrogen-related policies for Sri Lanka. Including in its analysis indirect policies that may not consider nitrogen in their formulation but potentially have implications anyhow for nitrogen management. By building a better understanding of the current nitrogen policy landscape both at the national and region level will support efforts to develop effective nitrogen management policies for the future.

Figure 7. Timeline of global and South Asian developments toward global cooperation on sustainable nitrogen management. Source: Raghuram et al. 2021



2 Country Level Profile and Priorities

Sri Lanka is an island located in the Indian Ocean with a surface area of 65,610 square kilometres. The country's West coast borders the Laccadive Sea, while the Bay of Bengal located at the Northeast influences the country's climate significantly. The country's longest and widest points are 432 km and 224 km, respectively. Pidurutalagala, standing at the height of 2,524 m above the sea level, is the highest mountain in Sri Lanka. Based on topography, rainfall regime, major soil type, land use, and vegetation, Sri Lanka has been divided into 46 Agro-Ecological Regions (AER) (Punyawardena, 2008). The diverse variability in climatic, edaphic and topographic characteristics has made Sri Lanka an island rich in bio-diversity and a home to a wide array of farming systems.



Map 1. Population densities of different districts of Sri Lanka

Source: Department of Census and Statistics, 2012

The annual rainfall in Sri Lanka is governed by the monsoons that produce four distinct rainfall seasons, i.e., the First Inter Monsoon (March – April), the South West Monsoon (May – September), the Second Inter Monsoon (October- November), and the North East Monsoon (December – February) (Punyawardena, 2020). The average annual temperature of Sri Lanka is 26.5 to 27.5 ° C. The average temperature ranges from a chilling low of 15 ° C in Nuwara-Eliya in the Central Highlands, to a high of 35 ° C in the coastal lowlands (Nissanka et al., 2011).

Sri Lanka is the home to a multi-ethnic population of slightly over 22 million people (CBSL, 2021). Sinhalese (74.9%) represent a majority of the population followed by Sri Lankan Tamils (11.2%), Sri Lankan Moors (9.2%) and Indian Tamils 4.2% (DCAS, 2012). Sri Jayewardenepura Kotte is the administrative capital city, while Colombo is the financial hub. Colombo and Gampaha districts in the Western province maintain the highest population densities where most of the townships in the country are concentrated (Map 1).

2.1 Socio-economic background

2.1.1 Administration

Sri Lanka, being a democratic republic and a unitary state, is governed by both presidential and parliamentary systems. Similar to many democracies in the world, the Sri Lankan government comprises of three branches; Executive, Legislative and Judicial. The executive president of the state, who is elected by the citizens of the country at a presidential election, holds the office for five consecutive years. The executive president, who serves as the head of state and the commander in chief of the armed forces, is entrusted with substantive authority in governance and political will. The legislative branch is represented by 225 parliament members who are elected at a general election by the citizens for a period of five years. Of the 225 parliament members, 196 members are elected in multi-seat constituencies and 29 are elected by proportional representation. The Supreme Court, a Court of Appeal, High Courts and a number of subordinate courts together make the judiciary system of the country. The legal system of Sri Lanka, particularly pertaining to criminal and civil laws, is mainly based on British law, Roman law and Dutch law. The Central government has adopted a bureaucratic system to facilitate state governance by dividing the country into nine provinces, with 25 district secretariats, 332 divisional secretariats, and 14,022 *grama niladhari* divisions (State Ministry of Home Affairs, 2021).

The 13th Amendment to the Constitution established provincial councils in 1987 and devolved some of the administrative powers hitherto exercised by the central government to the provincial governments. The Local governments, the third sub-level of the government system, consist of municipal councils, urban councils and pradeshiya sabha. The local governments are mainly responsible in providing local public services (e.g., roads, sanitation and recreational infrastructure) to the citizens in each respective locality. Members of both Provincial councils and local governments are elected by the citizens at periodic elections.

2.1.2 Economy

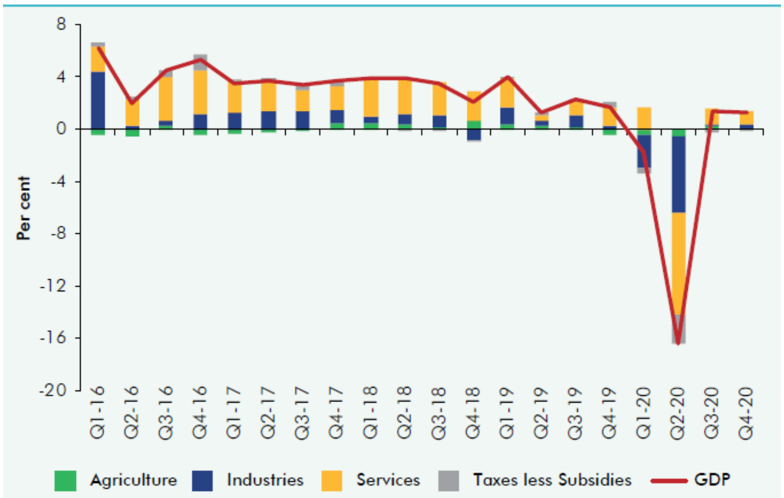
Sri Lanka, a developing economy in South Asia, recorded a continued rise in GDP per capita from 832.8 USD in 2001 to 4059.2 USD in 2018. However, since 2018, Sri Lankan economy has been declining and heading towards a crisis ignited by multiple factors including the crippling effect of the Covid-19 pandemic.

The service sector, with a contribution of 58.7% to the GDP in year 2020, remains the strongest pillar supporting the Sri Lankan Economy (Central Bank of Sri Lanka, 2020). The service sector consists of subsectors including wholesale and retail trade, transportation and storage, accommodation and food services, financial, insurance and real estate, information and communication (Central Bank of Sri Lanka, 2020). Agriculture contributes merely 7% to the GDP, while the contribution of industry has been recorded as 25.5% in 2020 (Central Bank of Sri Lanka, 2020).

The economy of Sri Lanka is largely dependent on foreign trade. Among the industrial exports, as of 2020, garments is the top source channeling highest earnings from merchandise exports into the national economy. Export earnings made through rubber products also make a notable contribution. Tea, followed by coconut and spices top the agricultural exports (CBSL, 2021). Sri Lanka primarily exports garments, tea, and rubber to the United States, the United Kingdom, and European countries. Expatriate workers’ remittance and tourism are the other two major channels through which Sri Lanka generates foreign revenue.

According to the Department of Census and Statistics' (DCS) Interim National Accounts Estimates, the Sri Lankan GDP fell by 3.6% in 2020, compared to 2.3% growth in the previous year. Due to nationwide lockdown measures imposed to contain the COVID-19 pandemic, the total contraction in 2020 was driven by a 16.4% year-on-year contraction in the second quarter of the year (Figure 8). Despite the disruptions caused by the second wave of the pandemic in October-November, the economy rebounded in the second half of the year, achieving real growth of 1.3% year-on-year (Central Bank of Sri Lanka, 2020).

Figure 8. Contribution of main sectors to the GDP in Sri Lanka from 2016 until 2020
Source: Central Bank of Sri Lanka, 2020



2.1.3 Agriculture sector

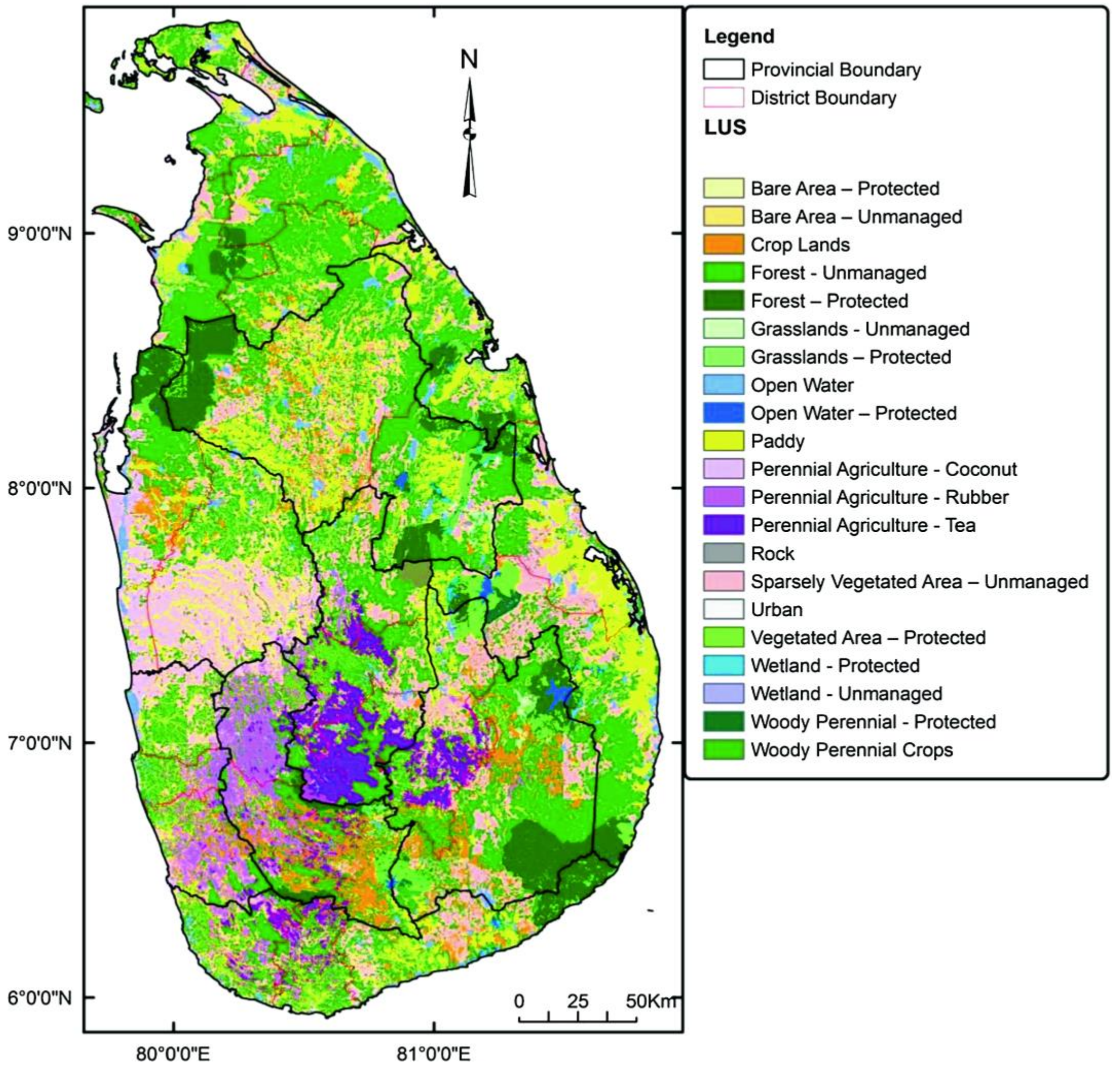
The agriculture sector sustains household economies of a majority of rural households and immensely contributes to foreign revenue. Over the course of history, agriculture has emerged to cover 42% of the landmass in Sri Lanka (Map 2). While plantation crops, such as tea, coconut, rubber and spices, have emerged as staple sources to tap foreign revenue, food crops and livestock sectors have improved food and nutritional security of the nation over the last decades. The above outcomes have also taxed the environment. Depletion of forest cover to provide room for agriculture has led to intense forms of human-wildlife conflicts (e.g., human-elephant conflict). Pollutants emitted from fertilizer and other agro-chemicals, such as N_20 and NH_3, have resulted in serious health and environmental issues.

The agriculture sector in Sri Lanka has undergone a number of distinctive changes during the post-independence period. These changes are mainly reflected in the changing patterns in production of different crops, average agricultural holding size, agricultural employment and the sector`s contribution to the national economy. The changes have brought mixed results that have been both favourable and unfavourable on the socio-economic conditions of the rural households involved in agriculture related livelihoods.

The economic importance and the state focus has shifted from export-oriented crop sector to the food crop sector over the last few decades. In 1962, 50% of the agricultural lands in Sri Lanka had been occupied by export-oriented plantation crops while rice (the staple food of the country) and all other food crops covered 35% of the agricultural lands (Bansil, 1971). In contrast, by the year 2013, out of the total extent of agricultural lands (2,205,395 ha), 56% (1,227,000 ha) had been under rice production alone (Department of Census and Statistics [DCAS], 2015; Central Bank of Sri Lanka [CBSL], 2015). On the other hand, the food crop sector`s contribution to the GDP has gradually increased over the contribution of the export-oriented plantation sector. Rice and other subsidiary food crops (excluding livestock and fisheries) alone have accounted for 43% of the contribution of agriculture to the GDP in 2013, whereas the export oriented plantation crops have contributed only 23% (CBSL, 2015).

With the emergence of the food crop sector, production of rice and other subsidiary crops have increased as a response to the increase in area harvested and yield. Sri Lanka achieved near self-sufficiency in rice towards the mid-1980s as a result of the progressive growth of paddy production. Import of food crops has significantly reduced and Sri Lanka has even started exporting certain food crops such as maize in small quantities. Increase in the production of food crops has favourably resulted to uplift the food security status of the country. Sri Lanka, in contrast to certain other nations such as India and Bangladesh, has not experienced famine during the last few decades due to the comparatively higher food consumption even among the poor households (Islam, 2005).

Map 2. Sri Lanka land use map. Source: Mapa (2020)



Despite the sector`s continuous fall over the industrial and service sectors which has been persisting for decades, it has shown a significant growth rate, during the last few years. For instance, the sector has shown a 5.5 percent growth during 2006 to 2010. According to the CBSL (2012), this growth has immensely contributed to the drastic reduction of poverty head count ratio from 15.2 percent in 2006/7 to 8.9 percent in 2009/10.

More than 99 percent of the agricultural holdings in Sri Lanka are within the range of 0.25 to 20 acres of extent and the average small holding land size currently rests at 1.85 acres (Agricultural Census, DCAS, 2012). According to Lokanathan and Kapugama, (2012), small agricultural holdings operate approximately 70.5% of the total land mass under agriculture in Sri Lanka and more than 70% of the rice farmers in Sri Lanka operate on less than one hectare of land (Aruna, 2013).

2.2 Natural resources of Sri Lanka

2.2.1 Soil

Sri Lanka's tropical climate, with year-round high temperatures and precipitation, results in highly weathered soils. A majority of Sri Lanka's soils are alfisols and ultisols. Wet[3] and semi-wet intermediate zones have ultisols, while dry and semi-dry intermediate zones have alfisols. Soil mineralogy reveals that soils in the dry and intermediate zones are younger and less weathered than soils in the wet zone (Mapa, 2020). As a result, the soil types found in different regions of the country vary significantly. There are a total of 28 soil series in the wet zone, 36 soil series in the intermediate zone, and 54 soil series in the dry zone of the country (Punyawardena, 2008).

Soil fertility is an important aspect related to agriculture. Soil fertility can reduce due to factors such as soil erosion, plant nutrient removal, leaching of plant nutrients, and decrease in soil organic matter content. To sustain continuous crop production in nutrient deficient soils, the Department of Agriculture has published site-specific fertilizer recommendations for each farming system (DOA, 2018). However, regardless of the recommendations, farmers tend to apply fertilizers beyond the recommended quantities everywhere that intensive agricultural techniques are practiced. Therefore, fertilizer overuse has polluted soils in numerous sections of the country, seriously threatening the environment.

2.2.2 Water

Sri Lanka, with a legacy of over two millennia old hydraulic civilization, is rich in both natural and manmade water sources. Sri Lanka has a diverse river system, with about 103 rivers flowing in a radial network starting from the central highlands. River Mahaweli, spawning from the heart of the central highlands, is the longest river in Sri Lanka.

There are over 18,000 man-made tanks in the dry and intermediate zones of Sri Lanka (Ranatunga, 1979). Most of these tanks in the dry zone had been built between the Anuradhapura and Pollonnaru reigns (437 B.C – 1212 C.E.). The water surface area of some of these tanks span an overwhelming 1000 ha. Ancient dry zone communities, by constructing these tanks, have transformed the non-arable dry zone into a thriving agricultural landscape. Later, larger reservoirs were constructed by the post-independence governments to generate hydro-power and channel water to new agrarian settlements that were established to enhance agricultural production in the country.[4]

2.2.3 Biodiversity

Sri Lanka is considered as a biodiversity hot spot due to the rich biodiversity of the country and high endemism that is threatened by human habitation (Conservation International, 2021). Sri Lanka is rich in genetic, species and ecosystem diversities. The Species diversity of fauna groups is very high (MOMDE, 2019). Figure 9a illustrates the percentage endemism of some fauna groups in Sri Lanka.

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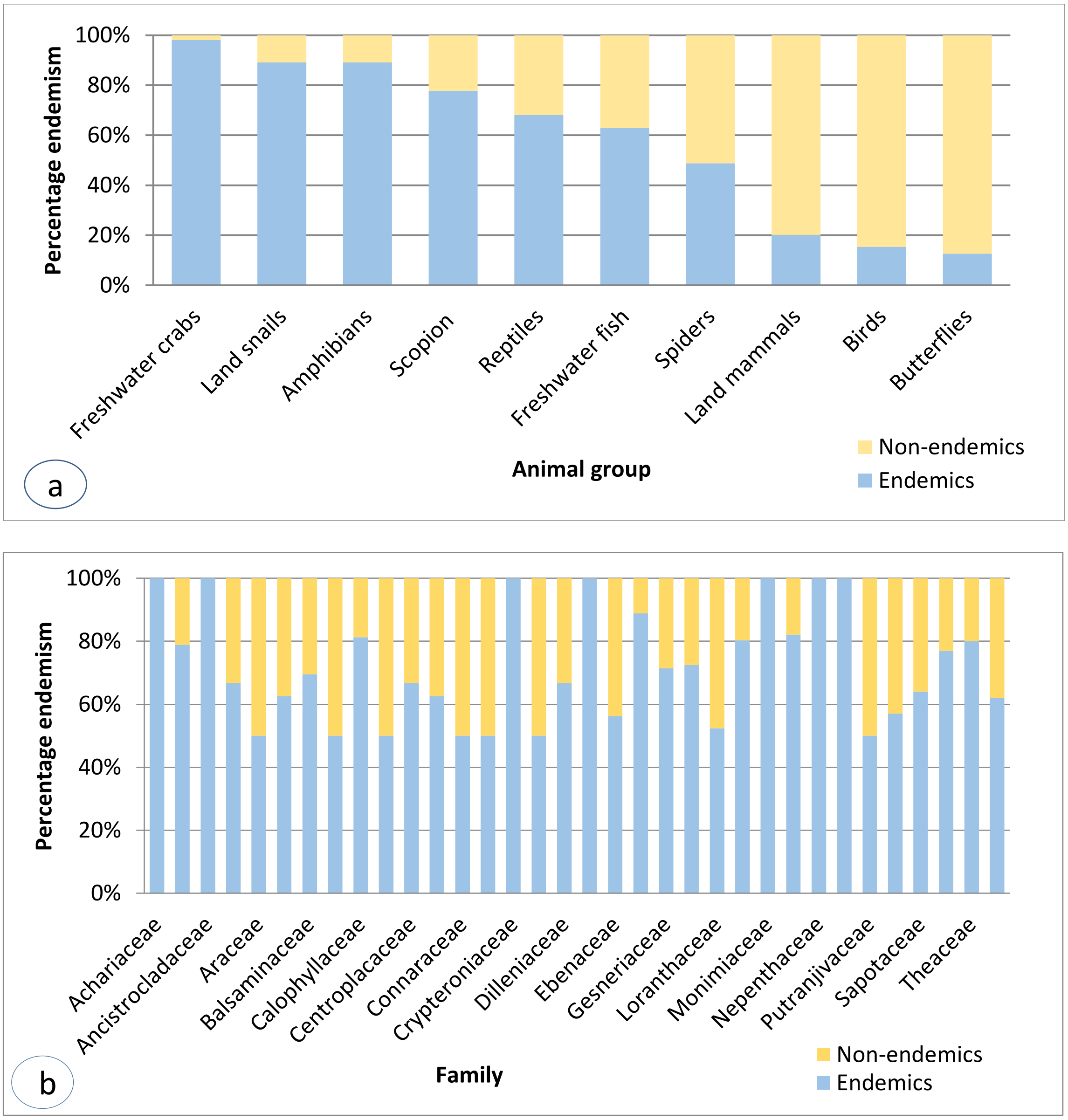
[3] Based on the annual average rainfall, Sri Lanka is categorized into three climatic zones: wet zone (>2500 mm), dry zone (<1750 mm), and intermediate zone (2500 – 1750 mm) (Rubasinghe et al., 2015)

[4] Sri Lanka gained independence from the Great Britain in 1948. The entire nation has been under the rule of British crown from 1815 to 1948. Prior to this period, the maritime provinces (except the Kandyan province) of Sri Lanka had been under the rule of the Portuguese (1506 to 1658 AD), the Dutch (1658 to 1796 AD) and the British (1796 to 1815 AD).

Furthermore, Sri Lanka is well known for its rich floral diversity. A total of 3116 flowering plant species in 1121 genera under 183 families are currently recorded in Sri Lanka. With 901 endemic flowering plants (MOMDE, 2019), Sri Lanka maintains a high floral endemism status. Out of 183 floral families, 96 families have at least a single endemic species, while 34 families have over 50% endemism value including seven families which are totally endemic to the country (Achariaceae, Ancistrocladaceae, Crypteroniaceae, Dipterocarpaceae, Monimiaceae, Nepenthaceae and Proteaceae) (MOMDE, 2019). Most of the flora is found in protected forest areas.

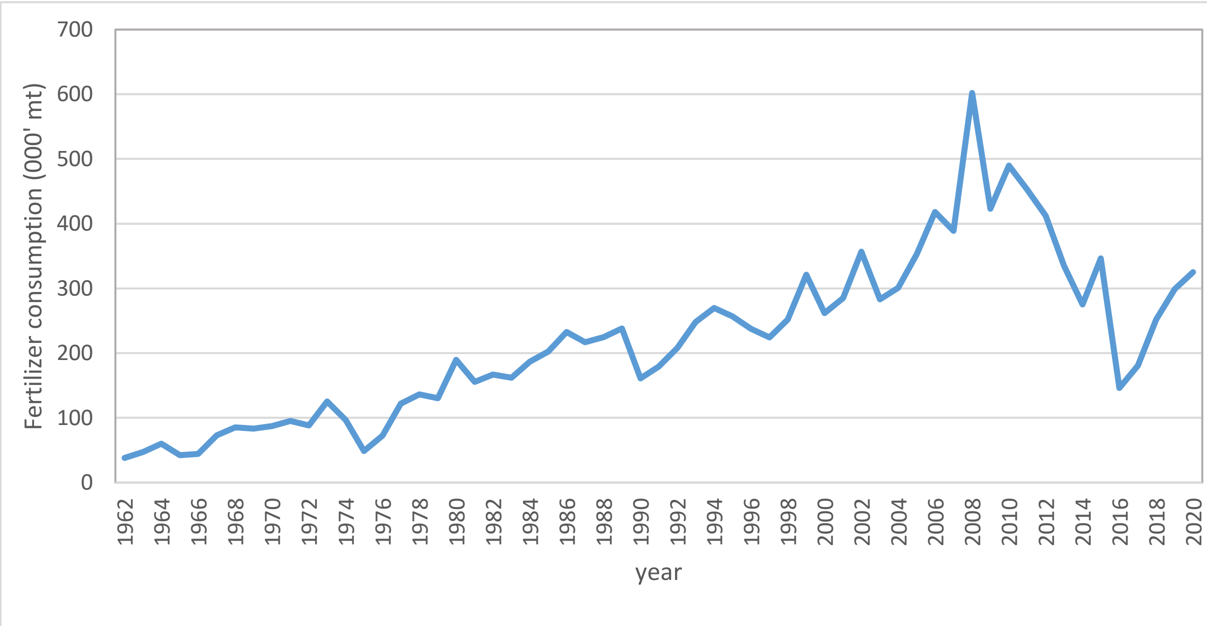
Figure 9. Percentage of endemic species from the total recorded species number (a) for some animal groups (b) for floral families (note: only families with over 50% endemism are shown in the figure).
Source: MOMDE (2019)



2.3 Agricultural nitrogen usage of Sri Lanka

The green revolution technologies[5], introduced to Asia during the mid-1960s, helped to boost the production of rice in the region with a distinctively sharp incline. Sri Lanka is one of the earliest nations in Asia to follow the green revolution as the country had fulfilled a decisive prerequisite - the need of irrigated water to a greater extent towards the early 1960s – to adopt the advanced agricultural inputs introduced by the movement. State-funded irrigation projects brought new lands under paddy and made the water demanding production technologies, such as improved varieties and fertilizer, feasible for the application by the small farmers. Just after the independence in 1948, 60% of the national rice requirement had been fulfilled through importation, but with the adoption of green revolution technologies under the patronage of post-independence governments, Sri Lanka could meet much of its rice requirement through domestic production towards the mid-1980s.

Figure 10. Total fertilizer usage for paddy in Sri Lanka 1962 - 2020



Source: National fertilizer secretariat, Ministry of Agriculture, Sri Lanka

Note: Total Fertilizer = Urea+Ammonium Sulphate+Triple Super Phosphate+Imported Rock Posphate+ Lanka Rock Phosphate+Murate of Potash+NPK+Dolamite+Others

Sri Lankan farmers began using synthetic fertilizers in the mid-20th century, which improved the quality and quantity of all agricultural yields. Since the independence, notably with the introduction of the fertilizer subsidy scheme for paddy in 1951, post-independence governments have generously and keenly promoted diffusion of synthetic fertilizer as an agricultural input across food as well as plantation crop sectors in Sri Lanka. Figure 10 depicts the trend in total fertilizer usage for paddy in Sri Lanka from 1962 to 2020. As figure 10 illustrates, fertilizer consumption in paddy has been increasing from 1962 to 2008. The dip in consumption, over the period from 2009 to 2016, can be attributed to reduction in paddy production due to a long spell of drought and certain policy instruments exercised by the government to regulate fertilizer usage in Sri Lanka. As of 2020, paddy sector has been the

[5] Consisted of an agricultural package of six elements; improved and certified seeds, fertilizers, insecticides, weedicides, transplanting and weeding (Fladby, 1983).

consumer of the largest fraction of synthetic fertilizer (44%). Nitrogenous fertilizers account for 66.1% of total fertilizer usage in 2020.

Nitrogenous fertilizer has made a big contribution to boost the food security status of the country. However, over and improper consumption of fertilizer by a majority of small farmers have interfered with the environment's nutrient balance, resulting in substantial environmental damage. These detrimental impacts of nitrogenous fertilizer on environment will be discussed in the following sections of this report

2.4 Environmental impact on nitrogen pollution

In Sri Lanka, there is a scarcity of information about nitrogen's effects on the environment and human health. However, it is undeniable that Sri Lanka's nitrogen emissions are rising, and numerous environmental problems are being increased as a result of it. (Table 3).

Agricultural practices are the main source of nitrogen emissions in Sri Lanka, as it is a country built on agriculture. Increased synthetic fertilizer use is the main cause of rising nitrogen levels in the atmosphere. In addition, as the country's industries develop, the industry sector contributes a substantial amount to national nitrogen emissions.

Table 3 demonstrates that between 2000 and 2014, the levels of all three nitrogen constituents, ammonia (NH_3), nitrogen oxides (NO_x), and nitrous oxide (N_2O), increased in Sri Lanka. The most significant shift has been in nitrogen oxides (NO_x), which increased by 42.9% from the year 2000 to 2015.

Table 3. National changes in emissions of key reactive nitrogen compounds, 2000-2015 for Sri Lanka

Sri Lanka	2000	2015	% Change
Ammonia (NH_3) emission (t/year)	59197.21	75395.5	27.4
Nitrogen oxide (NO_x) emission (t/year)	124676.35	178187.5	42.9
Nitrous oxide (N_2O) emission (t/year)	1477420	1867510	26.4

Source: European Commission, Joint Research Centre (EC-JRC)/Netherlands Environmental Assessment Agency (PBL). Emissions Database for Global Atmospheric Research (EDGAR), release EDGAR v6.0_GHG (1970 - 2018) of May 2021.

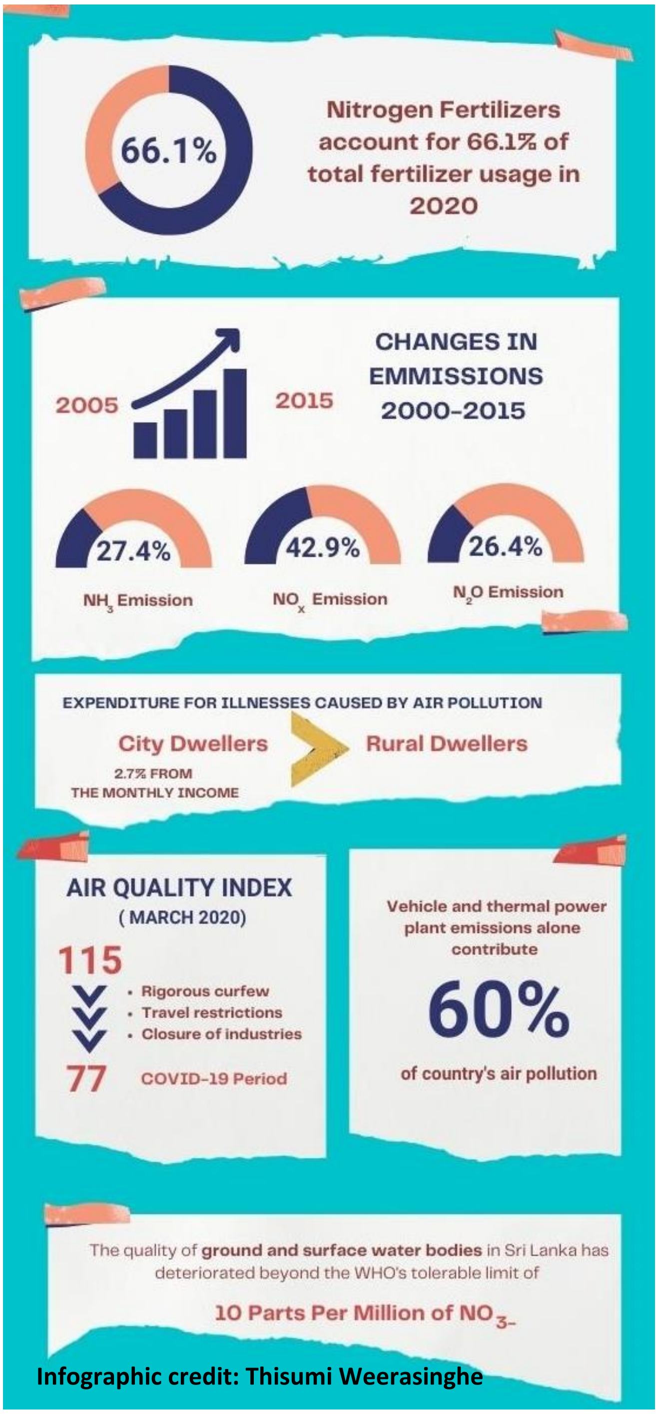
2.4.1 Air quality

Ammonia (NH_3) and nitrogen oxide (NO_x) emissions are air pollutants that have a negative impact on air quality. Human health effects and biodiversity losses are two direct effects of these reactive nitrogen compounds. Nitrous oxide (N_2O) is classified as a greenhouse gas with a global warming potential ~300 times greater than CO_2. The human respiratory system is affected by NO_x gases, while NH_4^+ ions indirectly induce respiratory diseases. Agriculture, transportation, and industry are the main sources of increased N_r levels in the atmosphere in Sri Lanka. However, Sri Lanka's air pollution mortality rate is still extremely low, at 0.008% (79.8 per 10,000 population) in 2016. (WHO, 2020). NO_x is formed by two gases incuding nitric oxide (NO), and nitrogen dioxide (NO_2).

Abeyratne and Ileperuma (2005) conducted research to determine the state of air pollution in the Kandy city region of the Central province. They discovered that in 14% of cases, ambient Nitrogen Dioxide (NO_2) concentrations in city areas surpassed Sri Lankan guideline values for ambient air (NO_2 < 0.050 ppm). They also found that densely populated city regions had higher NO_2 concentrations than less crowded city areas. The concentrations of NO_2 in rural areas are lower than in urban areas. They also found a link between high NO_2 levels and high fuel usage for automobiles and electricity generation by diesel power plants during droughts. They also claimed that the transboundary effect was also attributable to increase in NO_2 concentration. Despite being a coastal country, Seneviratne et al. (2011) reported that Sri Lanka's growing pollution levels were largely due to continental outflow.

Perera et al., (2019), conducted a time series analysis to study physical phenomenon of the relation among the ground level O_3, NO_x and VOC (Volatile Organic Compound). The authors could establish the significant effect of NO_2 in formation of ground level O_3 which is a secondary pollutant with harmful effects on human health. Senerath (2003) reports the effect of automobile exhaust in subjecting Sri Lankans to respiratory illnesses. Vehicle (petroleum) and thermal power plant emissions alone are shown to contribute for 60% of the country's air pollution (Ranaraja et al., 2019).

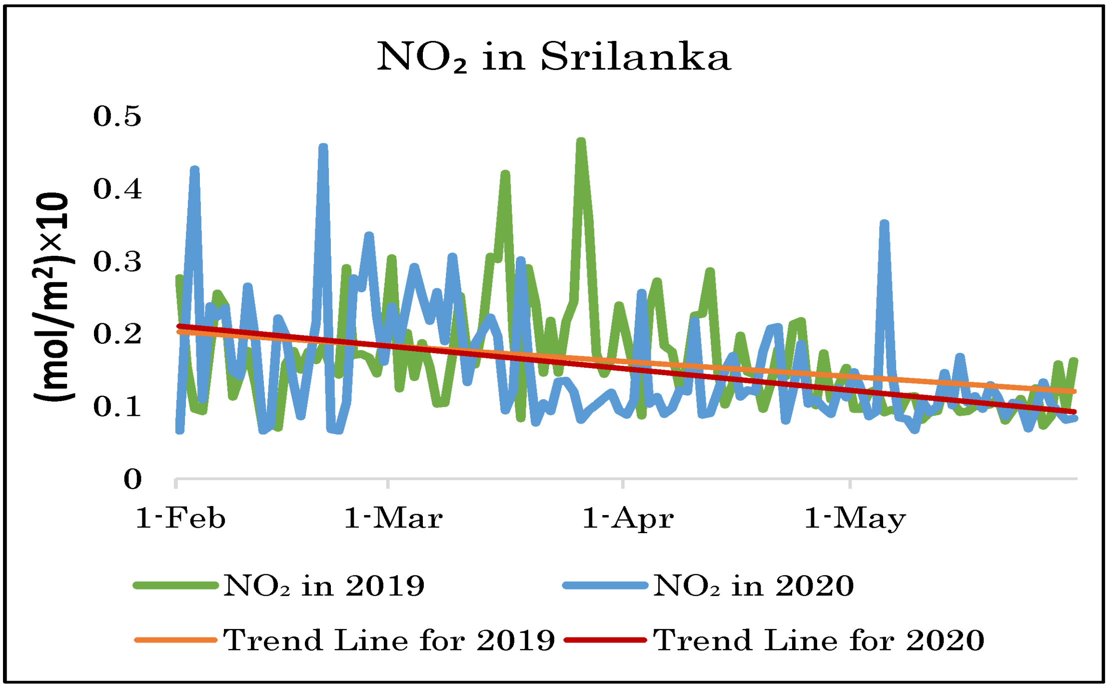
Meanwhile, Karunarathna et al. (2019) did a study in Kandy of the Central Province to determine the financial impact of air pollution. They pointed out that the city dwellers incur a higher expenditure than the rural dwellers to treat illnesses caused by air pollution. They also showed that this expenditure accounts for nearly 2.7% of people's monthly income in urban regions.



Infographic credit: Thisumi Weerasinghe

According to the National Building and Research Organization, Sri Lanka's air quality has usually been over 100 on the AQI (Air Quality Index) (Ranaraja et al., 2019). Following the rigorous curfew, transportation and travel restrictions, and the closure of industries in the face of COVID-19 pandemic, the AQI in Colombo dropped by 33% in the last week of March 2020 compared to the previous year (from AQI 115 to 77). The reduction in pollution in Colombo can also be linked to lower emissions in the neighbouring continental region.

Figure 11. Nitrogen dioxide (NO_2) concentration in Sri Lanka. Source: Hassan et al., 2021



As a result, NO_2 Concentration of Sri Lanka was also reduced. Figure 11 depicts the NO_2 concentration trend lines for 2019 and 2020. Values from February to May 2019 are represented by the solid green line, whereas values from February to May 2020 are represented by the solid blue line. The Sri Lankan government, as the Covid-19 cases surged, announced a state of emergency from March 22 to May 11, 2020, but in late April, the lockdown was lifted in a few regions. The level of NO_2 concentration in Sri Lanka was mostly higher before the lockdown period (1 February–21 March 2020) compared to the results from February–May 2019. The level of NO_2 concentration, on the other hand, decreased during the lockdown (Hassan et al., 2021).

2.4.2 Water quality

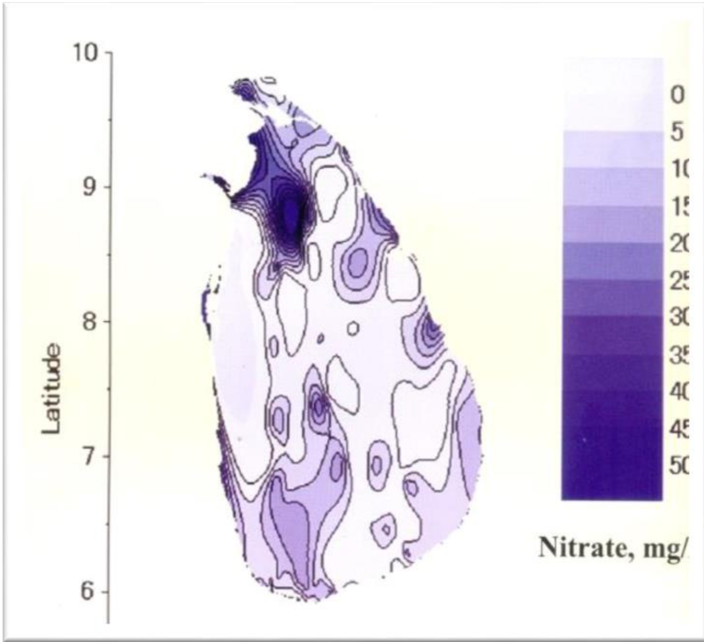
Water pollution in Sri Lanka by N_r compounds is mainly linked to agricultural practices. Excessive use of fertilizer by farmers degrades water quality by causing NO_3- to leak into groundwater and wash off into surface water sources. Waste water, discharged into natural water bodies by industries, is another critical source of Nitrogen pollutants induce algal bloom in inland waters resulting in serious impacts on aquatic species and human health. Many sources show that the quality of ground and surface water bodies in Sri Lanka has deteriorated beyond the WHO's tolerable limit of 10 parts per million of NO_3^- (Marambe and Nissanka, 2019).

Prabagar et al. (2020) and Jayasingha et al. (2011) found that there is a seasonal variability of nitrate concentration of ground water in Jaffna and Kalpitiya peninsulas where intensive farming is practiced. Nitrate concentration of ground water in Kalpitiya peninsula ranges way above the WHO standard in both wet (0.2- 148.5 mg/l) and dry seasons (0.6- 212.4 mg/l) (Jayasinghe et al., 2011). Map 3 depicts the various levels of nitrate in Sri Lankan groundwater.

According to Amarathunga et al., (2013) findings from a study conducted in the Upper Kotmale basin, levels of dissolved Ammonia-nitrogen are greater in places where sewage and farm animal waste are directly disposed into water sources. In places where intensive agricultural methods are used, dissolved nitrate and nitrite levels are high.

Map 3. Variation in nitrate levels in ground water of Sri Lanka

Source: Sri Lanka status report of sustainable nitrogen management, 2019



Reactive N_r compounds can pollute the coastal regions as well. For instance, nitrate enrichment causes corral bleaching in Sri Lanka by raising the acidity in seawater. In overall, eutrophication in fresh and coastal waters, triggered by N_r sources, has become a major problem in Sri Lanka.

2.5 Climate change

Climate change is the long term shifts in temperatures and weather patterns due to natural and anthropogenic causes. Natural causes include variations in the solar cycle. However, many anthropogenic activities, such as burning of fossil fuels, are known to be generating more greenhouse gases that entrap heat and raise global temperatures. Severe droughts, wild fires, floods, rising sea levels and declining bio diversity are some main effects of climate change (UN Climate Change, 2022).

Within the Sri Lankan context, numerous studies suggests that atmospheric temperature is in the increase affecting each and every agro-ecological region in the country (Nissanka et al., 2011; Sathischandra et al., 2014). Moreover, in the recent past, air temperature variations have shown evidence of climate change (Basnayake, 2007). Punyawardena et al. (2013a) observed that heavy rainfall events have become more frequent in upcountry regions. A higher variability in the rainfall in Yala season (one of the two cropping seasons in Sri Lanka) has increased over time, suggesting that it can even lead to shifting of agro-ecological boundaries that were previously defined based on the major climatic factors (Eriyagama et al. 2010; Punyawardena et al., 2013b). Continuous spells of drought also have been hampering the agriculture sector over the last few decades. For instance, the drought that prevailed from early 2016 to mid-2017 resulted in a drastic reduction of paddy production and made over 200,00 households reaching borderline food insecurity towards the end of the drought spell (FAO and WFP, 2017).

Even though a rise of sea level around 1-3 mm/year is observed in the Asian region (Cruz et al., 2007), it is anticipated that if the sea level were to increase by 1m in the Batticaloa region, the present permanent coastal vegetation front would likely to be shifted 30-45 m inwards towards the land affecting the diversity of the coastal vegetation (Mathiventhan et al., 2022).

3 Nitrogen-related Policy Analysis

3.1 Brief methods overview

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

This work builds on from an initial global nitrogen policy assessment conducted by Kanter et al (2020). Their global database had a collection of 2,726 policies from across 186 countries derived from the ECOLEX database. We adjusted the data collection approach and used multiple online data sources. We added to the 61 policies from South Asia identified by Kanter et al. from ECOLEX (2020) and created a new SANH policy database with a total of 966 polices for South Asia. The policies were collected during 2020-2021. See table 4 for the overview nitrogen-relevant policies collected per country. Sri Lankan nitrogen-related policies contribute 12% to the overall policies collected for South Asia.

Table 4. Total Number of policies and percentage per country in the SANH database, breakdown by policy data source, and relevance and impact scope

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

Source: SANH Database formulated by FAOLEX listings (http://www.fao.org/faolex/en/) corroborated and updated by SANH partners.

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 12 provides an overview of the methods.

Figure 12.An overview of the nitrogen policy assessment methods adopted by SANH.

1.COLLECTION

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

↓

2. FILTERING

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

↓

3. CLASSIFICATION

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

↓

4. ANALYSIS

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

3.2 Policy classification

The nitrogen-related policies collected were classified based on certain characteristics to identify patterns in the types of polices in place for each country. Policies were classified by: environmental sink; sector; sub-sector; policy type; pollution source type; impact direction; relevance; and impact scope. The classifications list is provided in Table 5. The classification approach followed closely the global study approach used by Kanter et al. (2020), with additional classifications. For classification definitions see Appendix 1.

Table 5. SANH nitrogen–relevant policy classification lists

<table>
<tr><th>Sink</th><th colspan="2">Sector/ Sub-sector</th><th>Policy Type</th><th>Pollution type</th><th>Impact Direction</th><th>Impact scope</th><th>Relevance</th></tr>
<tr><td>Air</td><td rowspan="6">Agriculture</td><td>Synthetic fertilizer</td><td>Regulatory</td><td>Point source</td><td>Positive</td><td>Large</td><td>High</td></tr>
<tr><td>Water</td><td>Aquaculture</td><td>Economic</td><td>Unspecified</td><td>Negative</td><td>Medium</td><td>Medium</td></tr>
<tr><td>Soil</td><td>Livestock</td><td>Framework</td><td>Both</td><td>Mixed /neutral</td><td>Small</td><td>Low</td></tr>
<tr><td>Climate</td><td>Multiple</td><td>Data & methods</td><td>N/A</td><td></td><td></td><td></td></tr>
<tr><td>Ecosystem</td><td>Agriculture other</td><td>Research & Development (R&D)</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Multiple</td><td>N/A</td><td>Commerce</td><td></td><td></td><td></td><td></td></tr>
<tr><td>N/A</td><td rowspan="5">Waste</td><td>Municipal waste</td><td>Pro-nitrogen</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Industrial/commercial waste</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Flood water</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Multiple</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>N/A</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Industry</td><td>N/A</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td rowspan="2">Food</td><td>Food safety</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Food security</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td rowspan="2">Energy</td><td>Low carbon and renewable</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Multiple</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Transport</td><td>Road transport</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td rowspan="3">Land use change</td><td>Forestry</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Other land use and land use change</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Multiple</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Urban dev. & tourism</td><td>N/A</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Other</td><td>N/A</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td rowspan="2">Multiple</td><td>Multiple</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>N/A</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>N/A</td><td>N/A</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

4 SANH Nitrogen-related Policy Dataset Results for Sri Lanka

Highlights

- This policy review analysed 115 national policies directly or indirectly related to N_r management in Sri Lanka. Of the above policies, 31 were of high relevance to N_r management with a large scope covering multiple sectors.
- Of the above 31 policies, 17 policies were strengthened with economic and/or regulatory instruments.
- 72% of the N_r related policies of Sri Lanka were oriented in their objectives/intents towards an identified sink, whereas 32% of the policies had explicitly recognized multiple sinks.
- A majority of policies (63%) indicated a positive impact direction, whereas only 4% of the policies indicated a negative direction with potential to increase N_r waste.

4.1 Relevance & scope

The nitrogen-related policies were classified according to their relevance and impact scope. These classifications enabled the filtering of policies according to their relevance to N_r management. Table 6 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.[6]

Table 6. Number and percentage of nitrogen-related policies in Sri Lanka for policy relevance and impact scope

Relevance			Impact scope		
Relevance	**Total No. of policies**	**% of policies**	**Impact scope**	**Total No. of policies**	**% of policies**
High (direct)	56	49	Large	**53**	46
Medium (indirect)	52	45	Medium	57	50
Low (indirect)	7	6	Small	5	4
Grand Total	**115**	**100**	**Grand Total**	**115**	**100**

Fifty six policies (49%) were classified with direct and 'high' relevance for Sri Lanka. Such policies included, for example, the 'National Environmental Act No. 47 of 1980' and the 'Fertilizer (Import, Manufacture and Formulation) Regulations, No. 1 of 2010.'

Indirectly relevant policies with 'medium' relevance do not contain one of the 29 key words but may feature synonyms of those words. We also expanded the list of key words to help identify such policies. Sri Lankan policies classified with medium relevance include, for example, 'Soil Conservation Regulations No. 01 of 2009' and 'Oil Spill Contingency Plan Regulations No 1 of 2012'. A total of 52 policies (45%) were classified as having medium relevance.

[6] The 29 key words were: fertilizer, manure, Nitrogen (N), Nitrogen pollution, nutrient pollution, nitrate, nitrates, ammonia, N oxides, nitrous oxide, N_2O, NH_3, NO_3, NO_x, eutrophication, hypoxia, air quality, air pollution, emissions, groundwater quality, groundwater pollution, freshwater quality, freshwater pollution, water quality, ozone depletion, climate change, greenhouse gas, agrochemical and effluent.

Those classified as having 'low' relevance were identified as having presumed indirect links with N_r due to their association with a certain sector(s) and/or sink(s). Seven policies (6%) were classified with low relevance, including, the 'Food Act No. 26 of 1980' and the 'Malathion Control Act No.22 of 1985'. Such policies remained in our collection. Although they had no direct reference to nitrogen they could still have implications on N_r management.

Table 6 also illustrates the number and percentage of policies, classified as large, medium and small for impact scope. Impact scope gives an indication of a policy's spatial coverage and its pertinence for N_r management. For example, those with a 'large' scope, a total of 53 policies (46%), include national level policies which have the potential to influence a large number of people and also classified as directly relevant to N_r management. Examples of such policies include the 'Tea Subsidy Act (No. 12 of 1958), or the 'The National Climate Change Policy of Sri Lanka'.

Fifty seven policies (50%) were classified with 'medium' impact scope including those which may be sub-national policies, or those less directly relevant to nitrogen, including the 'Soil Conservation Regulations No. 01 of 2009' and the 'National Environmental (Municipal Solid Waste) Regulations, No. 1 of 2009'.

The five policies (4%) with 'small' impact scope either focused on a very specific location or zone or were nationwide but with distant consequences for N_r management. These include, for example, the 'National Environmental (Upper Kotmale hydro power project - monitoring) Regulations No1 of 2003', and the 'National Health Strategic Master Plan 2016 - 2025'.

Of the total number of policies considered in the analysis, 108 (94%) policies were classified as being high or medium in relevance and 110 (96%) are large or medium in scope.

4.2 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 Sri Lanka there were 178 classifications from the 115 policies. 42 policies (37%) had more than one policy type identified. Policies with multiple instruments are favourable for N_r management since they indicate a more comprehensive approach.

Table 7. Number and percentage of nitrogen-related policies in Sri Lanka for policy type

Policy Type	Total No. of policies	% of classifications
Regulatory	13	7
Economic	12	7
Framework	101	57
Data & methods	20	11
R&D	14	8
Commerce	10	6
Pro-N	8	5
Grand Total	**178**	**100**

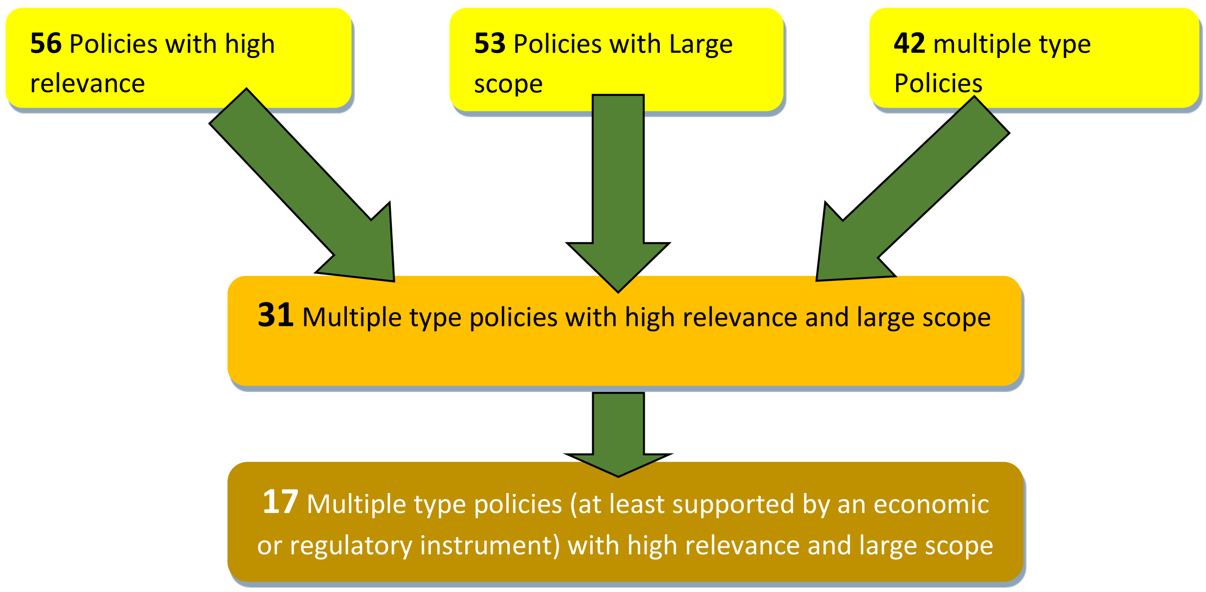
Table 7 illustrates the number and percentage of nitrogen-related policies in Sri Lanka by policy type. The most common classification for policy type is framework (57%). Such policies often include ones with broad objectives and/or designate governing bodies. For example, one framework policy is the

'Agrarian Development Act No.46 of 2000'. The next most common classification is data and methods (11%), followed by R&D (8%) and regulatory (7%), economic (7%), commerce (6%) and pro-N (5%). An example of a commerce policy is 'Regulation of Fertilizer Act, No. 69 of 1988'. A pro-N policy includes the 'Pasture Land (Reservation and Development) Act (No. 44 of 1983)' which has provisions to incentivize N_r use.

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'. Within the Sri Lankan Nitrogen policy list, there are 22 (19%) 'core nitrogen policies' equipped with by regulatory and/or economic instruments.

Relevance, scope and policy type, as three variables capturing quality of policies, can be combined into a simple index gauging relative importance and strength of policies related to N_r management. As depicted in Figure 13, among the list of 115 policies, there are 31 policies that are multiple in policy type, high in relevance and large in scope. We assume that these policies are relatively stronger than the other policies in terms of their effect on N_r management. Among the 31 relatively stronger policies, there are 17 'core nitrogen policies' strengthened with regulatory and/or economic instruments. These policies included, for example, the 'Chemical Weapons Convention Act, No. 58 of 2007', 'National Environmental (Protection and Quality) Regulations (No. 1 of 2008)' and 'Fertilizer (Import, Manufacture and Formulation) Regulations, No. 1 of 2010'. These 17 policies have a direct and significant influence on N_r management as they distinctively regulate the emission of N_r in processes mainly related to defence, waste, agriculture, transport and food sectors (*see* Appendix).

Figure 13. Strong and important nitrogen related policies in Sri Lanka.



4.3 Economic sector and sub-sectors

Table 8 provides an overview of the total number of Sri Lanka's nitrogen-relevant policies and percentages broken down by sector type and sub-sector type. The most common classification of policies was for multiple sectors at 32%. This is an advantageous policy characteristic indicating that multiple sectors have roles to play in N_r management. Some policy examples include the 'Marine Pollution Prevention Act, No. 35 of 2008' and 'Clean Air (2025): An Action Plan for Air Quality Management 2016'.

The second most common classification, as a single sector-oriented policy, is agriculture, at 15%. The other main sectors each featured only as a small percentage of the overall policy collection (ranging from 2% to 9%). Lastly, a considerable percentage (16%) of policies did not include a reference to any sector, i.e., the policy is focused only on one or more environmental sinks. An example is the 'Maritime Zones Law No. 22 of 1 September 1976'. While such policies should ideally be linked to sector actions, sink oriented policies are still considered positive (above sector-only oriented policies) because they focus on environmental protection and sustainability actions.

The category for sub-sectors (see Appendix 1 for the full classification list) identifies policies with a more specific sector focus. Non-applicable was the most common classification under this category as it is a default for policies that specify only a main sector, with no sub-sectors listed, or for policies that are generalised and do not refer to any specific area. The next most common sub-sector classification was 'multiple' (11%). These policies relate to agriculture, energy, land use change and waste, but do not relate to the more common sub-sectors identified. Two examples are the 'Forest Ordinance, the Flora & Fauna Act, the Fisheries Act. 1980' and the 'National Policy on Waste Management, 2019'. The next most common category, with a lower percentage overall, was for 'Agriculture, other' at 4%, including, for example, the 'National Policy and Strategy on Cleaner Production for Agriculture Sector 2012', and the 'National Agriculture Research Policy and Strategy: 2018 – 2027'. The rest of the sub-sectors were small in number with ≤3% policies.

Table 8. Number and percentage of nitrogen-related policies in Sri Lanka for sectors and sub-sectors

Main sector	No. of policies	% of policies	Sub-sector	No. of policies	% of policies
Agriculture	**17**	**15**	Agriculture other	**4**	**3**
			Aquaculture	2	2
			Livestock	2	2
			Multiple	4	3
			N/A	3	3
			Synthetic fertilizer	2	2
Energy	**3**	**3**	Low Carbon And Renewables	**2**	**2**
			Multiple	1	1
Food	**4**	**3**	Food safety	2	2
			Food Security	2	2
Industry	**3**	**3**	N/A	3	3
Land Use Change	**9**	**8**	Forestry	2	2
			Multiple	4	3
			Other Land Use And Land Use Change	3	3
Other	**9**	**8**	N/A	9	8
Transport	**2**	**2**	Road transport	2	2
Urban Development & Tourism	**3**	**3**	N/A	3	3
Waste	**10**	**9**	Flood water	1	1
			Industrial/ Commercial waste	3	3
			Multiple	3	3

			Municipal waste	2	2
			N/A	1	1
Multiple	**37**	**32**	N/A*	37	32
Sector not included	**18**	**16**	N/A	18	16
Grand Total	**115**	**100**	-	115	100
Note: For 'Industry', `Other`, `Urban development & Tourism`, no sub-sectors were assigned. For any main sector policy classified as 'Multiple', for sub-sectors they were by default classified as non-applicable. * N/A; Non-applicable *represents general sector policy that do not specify a sub-sector*					

4.4 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 appendix 1). As a category, sinks can also reflect the environmental aspect at risk (under threat) from N_r. A policy may refer to more than one sink, and if so, would be classified as multiple.

For Sri Lanka the most common classification was where 'multiple' had been included in the policy text (30%) (Table 9). This is considered a highly favourable characteristic as these policies address two or more sinks. Policy examples include the 'Town and Country Planning Ordinance No. 13 of 1946', the 'Mahaweli Development Board Act No. 14 of 1970' and the 'National Policy and Strategy for Cleaner Production 2005'.

Table 9. Number and percentage of nitrogen-related policies in Sri Lanka for environmental sinks

Sink	No. of policies	% of policies
Air	7	6
Climate	5	4
Ecosystem	20	17
Soil	5	4
Water	12	10
Multiple	34	30
N/A	32	28
Grand Total	**115**	**100**

However, the next most common classification was for N/A (28%). In other words, over a quarter of the policies collected were purely sector oriented. This could be regarded as an unfavourable characteristic in policies as it indicates that such policies have not considered the potential risks, or options to mitigate negative N_r environmental impacts. This included policies such as the 'Tea Subsidy Act (No. 12 of 1958)'. Certain environmentally related policies are also classified as N/A for sinks, because they are high level generalised policies such as the 'Sri Lanka Sustainable Development Act, No. 19 of 2017' which aims to account for sustainable development in policy but does not go deeper into the environmental aspects.

The most common single-sink focus was on ecosystem (17%), including for example the 'Fauna and Flora Protection (Amendment) Act No. 49 of 1993', followed by water (10%) such as the 'Marine Pollution Prevention Act, No. 35 of 2008'. The other single-sink focused policies (either air, climate, or soil) had a lower percentage of nitrogen-related policies associated with them (≤6%).

4.5 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 recognising the difference between pollution type sources. Point source and non-point source (NPS) pollution involve different challenges and different mitigation measures are 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. Only ten policies (Table 10) in our collection were identified as 'point source' e.g., the 'National Environmental (Ambient Water Quality) Regulations, No. 01 of 2019'.

Table 10. Number and percentage of nitrogen-related policies in Sri Lanka for pollution type source

Pollution type source	No. of policies	Percentage of policies (%)
Point source	10	9
Non-point source (NPS)	0	0
Both pollution type sources	17	15
Unspecified	26	23
Non-applicable	62	54
Grand Total	**115**	**100**

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 (Islam et al. 2018; Liu et al. 2020). No policies were identified as having targeted and noted only NPS.

Although it is beneficial for N_r related policies to recognise sources contribute to 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, recognising that different approaches are needed to tackle them. For Sri Lanka 15% of the policies achieved this, including the 'National Action Plan for Combating Land Degradation in Sri Lanka' and the 'National Policy on Waste Management, 2019'.

However, more policies (23%) specified neither point source nor NPS. This could be a disadvantage for a policy's ability to support sustainable N_r management. The 'National Drinking Water Policy 2000', and 'Action Plan for Haritha Lanka Programme (2009)' were both classified as unspecified. However, such policies could be amended to consider types of pollution sources, as appropriate.

Non-applicable was the most common classification (54%) 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.

4.6 Impact direction

Impact direction was introduced by the SANH study as a new classification to indicate whether a policy was presumed to have a positive, negative or mixed/neutral impact on N_r pollution. It is worth highlighting that this is based on the assessment of the policy text. Evidence of actual policy impacts on $N_{r,}$ whilst outside the scope of this study, 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.

For Sri Lanka it was encouraging that 63% of policies had a presumed positive impact, i.e., they promoted a reduction in N_r pollution and/or improved nitrogen management whether directly or indirectly. This included environmentally oriented policies like the 'National Water Supply and Drainage Board Law No. 2 of 1974' and 'Land Reclamation and Development Corporation Act No. 52 1982'.

Only a small number (4%) of policies were indicated with a potentially negative impact, i.e., where environmental considerations were absent from the policy text. This is an unfavourable policy indicator as such policies have the potential to increase nitrogen waste, by causing excess N_r. Polices classified as negative impact include the 'Paddy Lands Act, No. 1 of 1958', and 'The National Livestock Breeding Policy Guidelines and Strategies for Sri Lanka 2010'.

The third classification for impact direction was 'mixed/neutral' which identified policies that may have both positive and negative impacts, e.g. a policy that aims to enhance food production and increase access to fertilizer but also considers the environmental impacts, or a policy that is potentially neutral in its impacts (i.e., neither positive nor negative). 33% of all 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 (Table 11). Further assessments of the positive and mixed/neutral policy group would be needed to identify how far these policies could achieve sustainable outcomes.

Table 11.Number and percentage of Sri Lanka nitrogen-relevant policies for impact direction

	No. of policies	**Percentage of policies (%)**
Mixed /neutral	38	33
Negative	5	4
Positive	72	63
Grand Total	115	100

5 Cross Comparative Policies

Highlights

- Among the N_r related policies for Sri Lanka, there are 9 policies (8%) with 'integrated objectives' that refer to multiple sinks, multiple sectors and include multiple policy instruments.
- Pollution source type is included in only two of the policies out of then 9 policies.
- Policies with high/direct relevance should be a recommended priority to ensure that they do address pollution sources and consider multiple sectors and sinks etc. to avoid contribute to increasing N_r emissions, benefiting the environment and society.

In this section the policies are cross compared by the classifications for sink and sector, sink and policy type, sector and policy type. These cross comparisons enable patterns to be further assessed to identify strengths and weaknesses in promoting sustainable N_r management.

Table 12 illustrates the sector and sink policy results. Most combinations had low percentages, i.e., ≤5%. The most common combination was for multiple sector policies that refer to multiple sinks (17%). Policy examples include the 'Coast Conservation Act No. 57 of 1981' and the 'Sri Lanka Comprehensive Disaster Management Programme 2014 - 2018'. These policies are favourable as they indicate 'integrated objectives' that consider both the multiple environmental aspects as well as multiple sectors.

The next most common combination is agricultural sector policies that have not considered any specific sink (8%). This includes policies such as the 'Control of Pesticides (Pest Control Services) Regulations No. 01 of 2010'. Any single-sector focused policies that overlook sinks would benefit from further review and possible adjustments to mitigate negative environmental impacts.

Table 12. Percentage of nitrogen-related policies by sink and sector, from Sri Lanka

Sink	Agriculture	Energy	Food	Industry	Land Use Change	Multiple	N/A	Other	Transport	Urban Dev. & Tourism	Waste	Grand Total
Air	0	0	0	1	0	1	3	0	2	0	0	6
Climate	0	0	0	0	0	4	0	0	0	0	0	4
Ecosystem	2	0	0	0	7	4	4	0	0	0	0	17
Multiple	3	0	2	1	0	17	3	0	0	0	4	30
N/A	8	3	2	1	0	3	0	8	0	3	2	28
Soil	2	0	0	0	1	1	1	0	0	0	0	4
water	0	0	0	0	0	3	5	0	0	0	3	10
Grand Total	**15**	**3**	**3**	**3**	**8**	**32**	**16**	**8**	**2**	**3**	**9**	**100**

5.1 Policy by sink and policy type

Table 13 illustrates the sink and the policy type classifications for nitrogen-related policies from Sri Lanka. From the results most of the combinations of policy type and sink range from 0 to 3%. The most common combination (18%) was for framework policies with multiple sinks including for example the 'National Policy on Waste Management, 2019'. Following this, framework policy types, with no specific sink, were the next most common combination (15%). Framework policies also had a higher percentage (relative to other combinations) for eco system (11%) and water (6%) sinks. These overall results illustrate that framework is the predominating policy type for single sink-oriented policies. Those policies with multiple sinks and having multiple policy types would be considered better suited for N_r management as they are considered to have more integrated objectives and approaches.

Table 13. Percentage of classifications by policy type and sink for Sri Lanka's nitrogen-related policies

Sink	Regulatory	Economic	Framework	Data & methods	R&D	Commerce	Pro-n	Grand Total
Air	3	0	1	3	0	2	0	9
Climate	0	0	3	1	1	0	0	5
Ecosystem	0	0	11	1	2	0	1	14
Multiple	1	3	18	3	4	2	2	34
N/A	2	3	15	2	1	2	1	26
Soil	0	0	3	0	1	0	1	4
Water	1	0	6	2	0	0	0	8
Grand Total	7	7	57	11	8	6	4	100

The percentage is calculated from the total number of classifications (i.e., 178) and not the total number of policies. This is because one policy could contain multiple policy types.

5.2 Policy by sector and policy type

In table 14 the classifications for policy type and sectors are compared. As with sinks, the majority of combinations indicate a low percentage ≤4%. The exception for single sectors includes 'agriculture' in relation to 'framework' type policy features as the second most frequent pair (7%). Similar to sinks, the category for 'multiple' sectors was also more commonly linked to certain policy types including, in descending order: framework, as the most common combination (20%), R&D (4%), data and methods (3%) and economic (3%) policy types. Again if those policies are associated with multiple sectors and having multiple policy types, these would be considered better suited for N_r management.

Table 14. Percentage of classifications by policy type and sector for Sri Lanka's nitrogen-related policies

	Policy Type							
Sectors	**Regulatory**	**Economic**	**Framework**	**Data & methods**	**R&D**	**Commerce**	**Pro-N**	**Grand Total**
Agriculture	1	2	7	1	1	2	2	17
Energy	0	0	2	0	0	1	0	2
Food	0	0	2	1	1	0	1	5
Industry	0	0	2	0	0	0	0	2
Land use change	0	0	5	0	1	0	0	6
Multiple	1	3	20	3	4	1	1	33
N/A	2	0	8	3	0	1	0	14
Other	1	1	5	1	1	1	0	8
Transport	1	0	1	1	0	1	0	3
Urban Dev.& Tourism	0	0	2	0	0	0	0	2
Waste	2	1	5	1	0	0	0	8

Grand total	7	7	57	11	8	6	5	100

5.3 Policy sector, sink and policy type

In all of the above cross comparisons, 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 N_r management. From Sri Lanka there are 9 policies (8%) that hit all these criteria. These policies stand out as they refer to multiple sinks, sectors, and include multiple policy types. In addition all of these policies have been classified as being of high or medium relevance and large or medium impact scope. The 9 policies are outlined in Table 15.

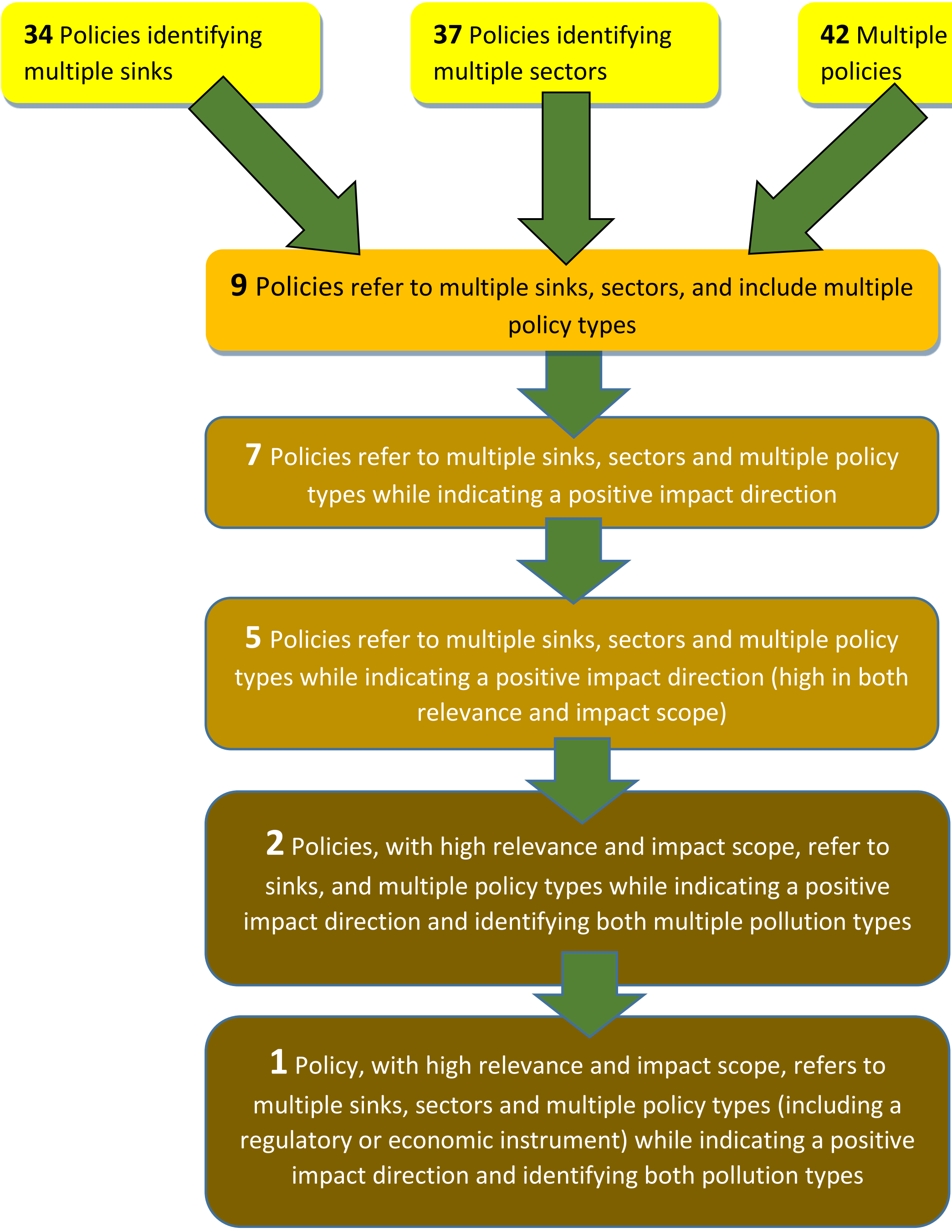
Table 15. Sri Lanka nitrogen-related policies that refer to multiple sectors, sinks and mixed policy types and classification for impact direction and pollution source type

Policy name	**Impact direction**	**Pollution Source Type**
Agrarian Services Act. (No. 58 of 1979)	Mixed /Neutral	Unspecified
National Environmental Act No. 47 of 1980	Positive	Unspecified
National Environmental (Amendment) Act, No. 56 of 1988	Positive	Both
Coast Conservation Act No. 57 of 1981	Positive	Unspecified
North Western Province Environmental Statute No. 12 of 1990	Positive	Point source
Coastal Zone Management Plan (CZMP) 2006	Positive	Both
Ten Years Development Policy Framework of The Fisheries and Aquatic Resources Sector 2007 - 2016	Positive	N/A
Action plan for Haritha Lanka Programme (2009)	Positive	Unspecified
Vision 2025 (A Country Enriched)	Mixed / Neutral	Unspecified

In terms of recognising pollution source types (Table 15), also a desirable policy characteristic, from the nine policies only one policy refers to point source and two policies refer to both pollution types (NPS and point source). Five policies were classified as unspecified and one as N/A in pollution source type. The two policies that were classified for recognising both pollution types stand out further as policies with the strongest potential to deal with the complex nature of N_r management. These two policies include the 'National Environmental (Amendment) Act, No. 56 of 1988' and the 'Coastal Zone Management Plan (CZMP) 2006'. The 'National Environmental (Amendment) Act, No. 56 of 1988' stands out above all the policies as the policy with high relevance and impact scope while having all the features deemed favourable for a N_r management policy as described earlier (Figure 14).

However, since the *effectiveness* of a policy is predicted by a variety of internal and external factors, the actual impact of any policy *in practice* is beyond the scope of this analysis and would require further investigation. However, having these policy characteristics would be encouraged in policy interventions to address the N challenge via amendments (such as the aforementioned policy) to existing policies, especially those with higher N relevance.

Figure 14. Relative importance and strength of N_r policies



Box 2: Three "integrated" environmental policies

The 'National Environmental Act no. 47 of 1980'; The 'National Environmental (Amendment) Act, No. 56 of 1988'; The 'National Environmental (Protection and Quality) Regulations, no. 1 of 2008'

Ministries responsible: All three policies are under the responsibility of Sri Lanka's Ministry of Environment.

Sector/sinks: Multiple sinks are covered by all three outlined policies. The two Acts cover multiple sectors, whereas the regulations are centered on waste, or more specifically the 'issue of environmental protection license for emission or disposal of waste'.

Policy type: Each of the policies is legislation and includes multiple policy instruments. As they include regulatory and economic elements the three of them are considered 'core' policies. Both acts are broader umbrella framework policies that also feature economic regulations. But the National Environmental Act no. 47 of 1980 features research and development (R&D) and the National Environmental (Amendment) Act, No. 56 of 1988 features data and methods and commerce. The National Environmental (Protection and Quality) Regulations, no. 1 of 2008 has both regulatory instruments and guidelines/ standards for data and methods.

Overview: Environmental Protection was recognized as a national priority by Article 27(14) of the national constitution; 'The State shall protect, preserve and improve the environment for the benefit of the community'. Soon after the national constitution was formally adopted in 1978, the 'National Environmental Act no. 47 of 1980' was enacted. This Act was a pivotal turning point as it established the Central Environment Authority, which is the main institution entrusted with the authority to oversee the health of the environment. The act has undergone multiple amendments and supported numerous regulations (Wijayadasa & Ailapperuma, 2014) and is considered a central policy node in our analysis. The Act itself does not refer to nitrogen directly but does refer to the prevention of pollution from wastes and emissions.

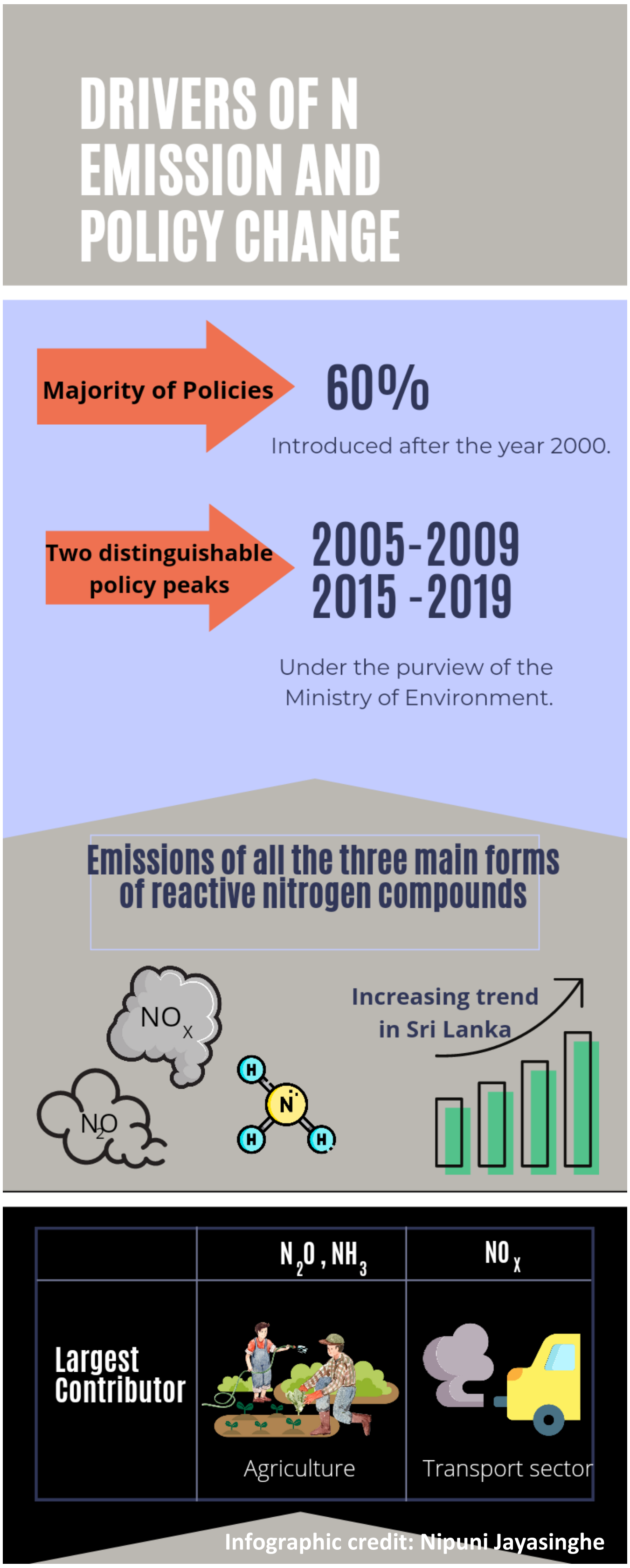
The Central Environmental Authority was given wider regulatory powers under the National Environment (Amendment) Act, No. 56 of 1988. The Authority is vested with the power to carry out Environmental Impact Assessment (EIA) for assessing the impact of development projects on the environment and public participation was also introduced to the Environmental Impact Assessment process. Environmental Protection License Scheme, Prohibition of the discharge, emission, or deposit of waste into the environment, Restriction regulation and control of pollution of the inland waters, atmosphere, and soil, Restriction on noise pollution were some of the key attributes of the Act No. 56. As with Act No. 47, this act also does not refer to nitrogen directly but does refer to the prevention of pollution from wastes and emissions.

With the rapid industrial development of the country, environmental pollution had significantly increased from the early 1980s (see Table 23. Motor vehicles emerged as the most prominent contributor to air pollution, contributing up to 60% of total emissions in the capital city; Colombo (Batagoda et al, 2004). Following recognition of these issues, "the National Policy on Urban Air Quality Management" and "the Colombo Clean Air 2000 Programme" were adopted. The National Environmental (Protection and Quality) Regulations, No. 1 of 2008 is a notable policy as being directly relevant to reducing nitrogen pollution by setting constraints and standards for effluent discharged by both industrial and domestic entities. The standards set the tolerance limit for nitrogen and ammonia emitted to inland surface waters and marine coastal areas through industrial waste.

6 Drivers of N Emission and Policy Change

Highlights

- A majority of policies (60%), relevant to N_r management have been introduced after the year 2000.
- The periods during 2005-2009 and 2015-2019 mark two distinguishable policy peaks.
- Over 50% of the policies introduced within 2005-2009 (59%) and 2015-2019 (56%) have been introduced under the purview of the ministry of environment.
- Recent governments have taken a number of positive policy initiatives to curb N_r pollution caused by agriculture, industrial, waste, land use, energy and transport sectors in Sri Lanka.
- Emissions of all the three main forms of reactive nitrogen compounds, ammonia, (NH_3), nitrogen oxides (NO_x), and nitrous oxide (N_2O), shows an increasing trend in Sri Lanka.
- Agriculture has been by far the largest contributor of N_2O and NH_3 emissions in Sri Lanka over the last two decades.
- Transport sector has emerged as the top contributor to national NO_x emissions in Sri Lanka.

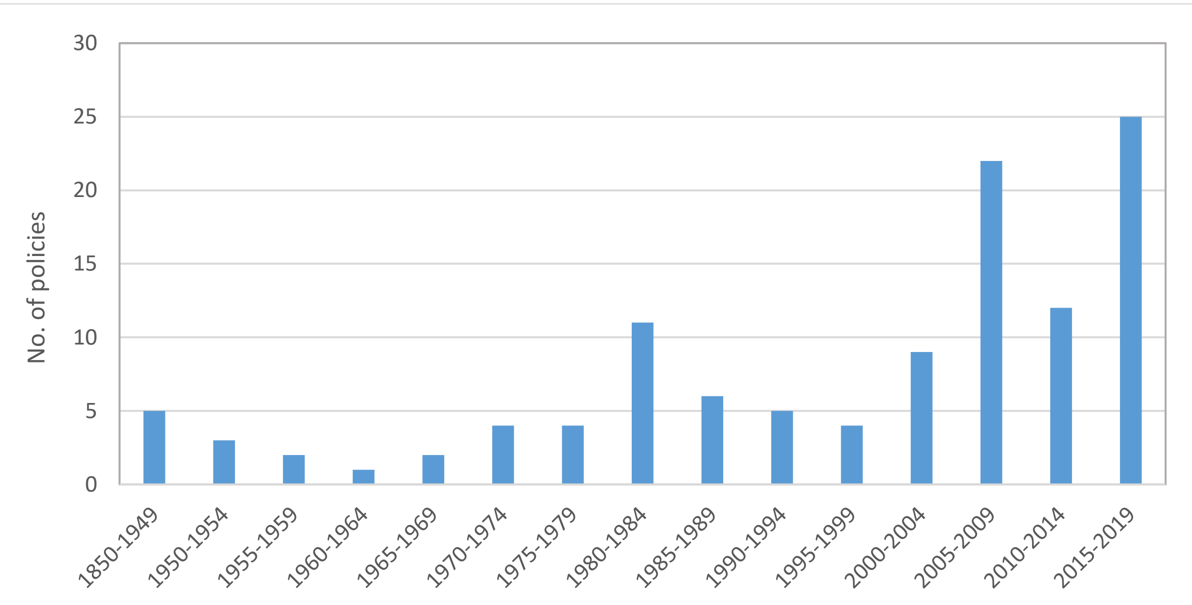


6.1 Nitrogen related policies with time series

Figure 15 illustrates the chronology of nitrogen related policies in post-independence Sri Lanka. Our online search could only capture five N_r management related policies that had been introduced by the British Colonial government prior to 1948. As the figure shows, there is a clear surge of N_r policies in Sri Lanka within the first two decades of the new millennium. Nearly 60% (68 policies) of the policies have been introduced within the aforementioned period. Further, of the 72 policies with positive impact direction, 49 (68%) have been introduced after the year 2000. The two policy peaks, 2005-2009 and 2015-2019, within the last two decades overlaps with the first spells of two successive governments. Over 50% of the policies introduced within 2005-2009 (59%) and 2015-2019 (56%) have been established under the purview of the ministry of environment. There is another distinguishable policy peak within the five year period from 1980-1984. This peak is mainly attributable to the urban and land development acts introduced by the land and urban development ministries of the respective period. Further, the ministry of environment has introduced the highest number of policies (74% of the total) with a positive impact direction in the new millennium. Overall, our analysis indicates a developing political context where environment sustainability is gaining much attention as a priority.

There are also distinguishable sector specific policy trends identified within a few major sectors (*see* the Appendix). Our analysis shows that the agriculture sector has maintained a static momentum in introducing N_r related policies over the time. All the N_r policies with negative impact direction are related to the Agriculture sector, whereas a majority of the N_r policies have mixed/ neutral impact direction. The only two agriculture sector specific policies with a positive impact on N_r management have been introduced within the last decade. Of the two positive policies, "National policy and strategy on cleaner production for agriculture sector" is a framework policy, while the other (Collecting, holding and supplying of shrimp brooders in order to breed brackish-water shrimps (Penaeus species) regulations no. 2 of 2017) is a regulatory type policy with a medium impact scope. While the lately added two positive policies indicate a progressive concern of the sector to regulate N_r use, the absence of stronger core policies indicates a policy gap within a sector that largely contributes to nitrogen pollution in Sri Lanka.

Figure 15. Chronology of N_r related policies in Sri Lanka.
Source: SANH database (Yang et al. 2021)



Following the agriculture sector, 'waste' and 'land use change' sectors have established the most number of sector specific N_r related policies. Most of the N_r related policies (80%) applied to the waste sector were accumulated after the year 2008. Of all the single sector policies with a positive impact direction that were introduced after the year 2000, a majority (41%) of the policies have targeted the waste sector. The recent interest of the government to manage waste was distinctively manifested by a policy document launched in 2008 to make Sri Lanka a waste-free country by 2018. When it comes to the land use change sector, more sector-specific policies were established after 1980, and concentrated after the year 2005.

Figure 16. Establishment of Sri Lankan N_r related policies by sink

Source: SANH database (Yang et al. 2021)

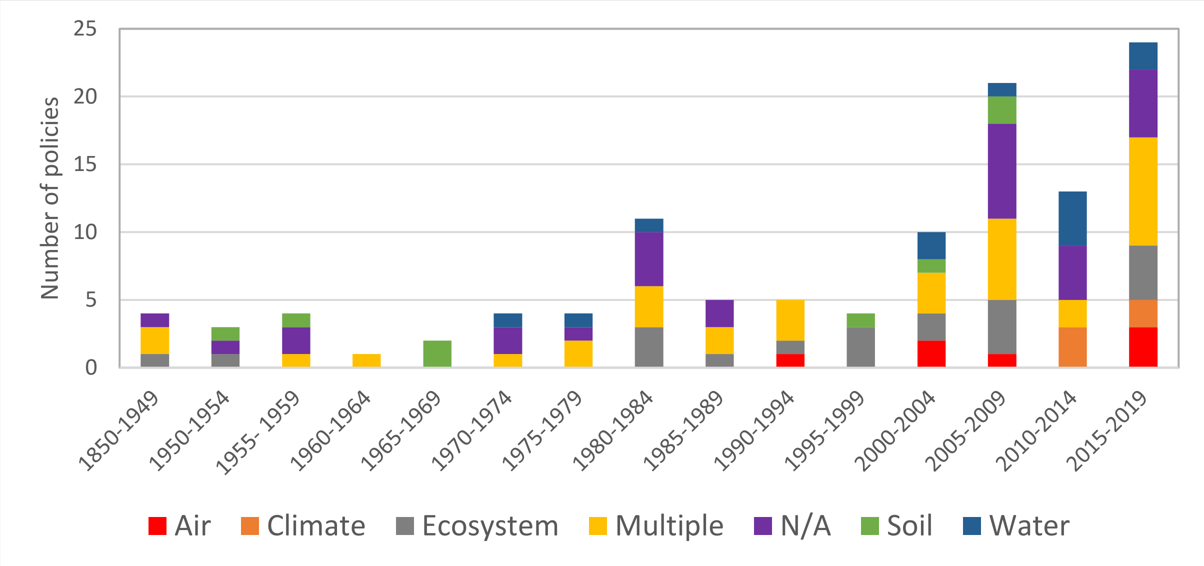


Figure 16 illustrates the sink breakdown of policies established in Sri Lanka in chronological order. The classification for 'no specific sink' and 'multiple' were higher compared to other sinks all the time. Notably almost all the policies targeting climate and air are recent additions to the policy list i.e. since 1990's. Particularly, all the policies identifying climate as a sink were introduced only after 2011. It can be assumed that the recent global climate change discussions, which have intensified over the last decade, have encouraged the Sri Lankan government to formulate N_r related policies aimed at addressing the climate related risks and challenges.

6.2 Trends over time in reactive N_r emissions

Emissions of all the three mains forms of reactive nitrogen compounds, ammonia, (NH_3), nitrogen oxides (NO_x), and nitrous oxide (N_2O), shows an increasing trend in Sri Lanka (Figure 17). N_r emission data was sourced by EDGAR and Emissions Database for Global Atmospheric Research developed by the Joint Resource Centre (JRC). EDGAR provides independent estimates of emissions compared to those reported by European Member States or by Parties under the United Nations Framework Convention on Climate Change (UNFCCC), using international statistics and a consistent IPCC methodology. SANH selected EDGAR as the common data source for N_r emissions to enable comparability and consistency across our analyses of the eight SA countries.

The environment responds to the different N_r compounds in different ways. N_r enters the environment by a variety of sources and states, not only as atmospheric emissions but also entering soils and water. For this report we assess, in the absence of other nationwide data of other sinks, emission trends, which reflects directly to the environmental sinks, air and climate but also indirectly, due to nitrogen cascades, to other sinks (Galloway et al., 2003).

Nitrous oxide (N_2O): Emissions of N_2O, which is a major greenhouse gas and the primary source of stratospheric ozone depletion in the twenty-first century (IPCC, 2014), has slightly increased by 8% from 2000 to 2018 (Table 16). However, change in N_2O emission for certain sectors during the same period shows a significant rise, i.e., power industry (393%) and transport (113%). In 2018, 'other sectors', which includes agriculture, was Sri Lanka's top contributor to N_2O emissions (85%) (Table 16). The buildings industry (6%) was the second-largest generator of nitrous oxide (N_2O) emissions in 2018, even though it has decreased 17% from 2000. Other sectors' contributions to nitrous oxide (N_2O) emissions, such as "transport" (3%), "power industry" (2%), and "other industrial combustion" (5%), were minor (<5%), but each sector has experienced significant increases in emissions since 2000.

Figure 17. Trend in Sri Lanka total N_2O emission by sector per year from 1970 to 2018 Note: EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b)

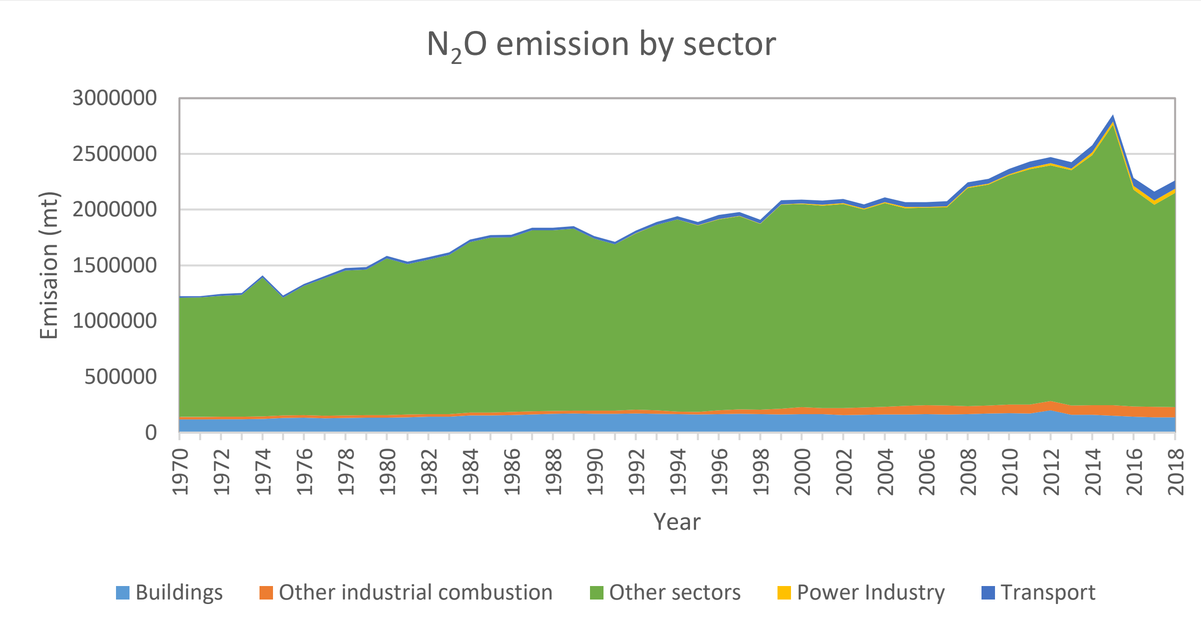


Table 16. Total Nitrous oxide (N_2O) emissions per sector between 2000 and 2018 (Gg per year) and percent change

Main Sector	2000 (Tonnes)	2000 (as a % of total emission)	2018 (Tonnes)	2018 (as a % of total emission)	% change 2000 and 2018
Buildings	164380	8	135893	6	-17
Other industrial combustion	65139	3	93600	4	44
Other sectors	1819303	87	1922087	85	6
Power Industry	7224	< 1	35618	2	393
Transport	35006	2	74631	3	113
Total N_2O	**2091052**	100	**2261829**	100	8

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

Ammonia (NH_3): NH_3 is being increasingly recognized as a significant component of air pollution budgets (Martin et al., 2006). Emissions of NH_3 in Sri Lanka have increased by 27% from 2002 to 2015. Agriculture has been by far the largest contributor of NH_3 emissions in Sri Lanka over the last two decades (Table 17). Agriculture contributed to 67% of the total ammonia (NH_3) emissions in the year 2015 Buildings accounted for the second-largest contribution, accounting for 22% of total emissions, which includes small-scale non-industrial stationary combustion. In 2015, the contribution of 'other industrial combustion' to total NH_3 was 11%. Other sectors such as 'Waste,' 'Transport,' 'Power industry,' and 'Other' contributed very little to NH_3 emissions (< 1%).

The sources of ammonia emissions have changed to varying degrees. Ammonia emissions were reduced in some sectors, such as 'Building,' 'Power industry,' and 'Other,' which saw reductions of 6%, 31%, and 82%, respectively (Table 17). Despite its small overall contributions to NH_3 emissions in 2015 (<1%), the transport sector shows the largest increase (96%) (Figure 18).

Figure 18. The trend in Sri Lanka total NH_3 emission by sector per year from 1970 to 2015 Note: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a).

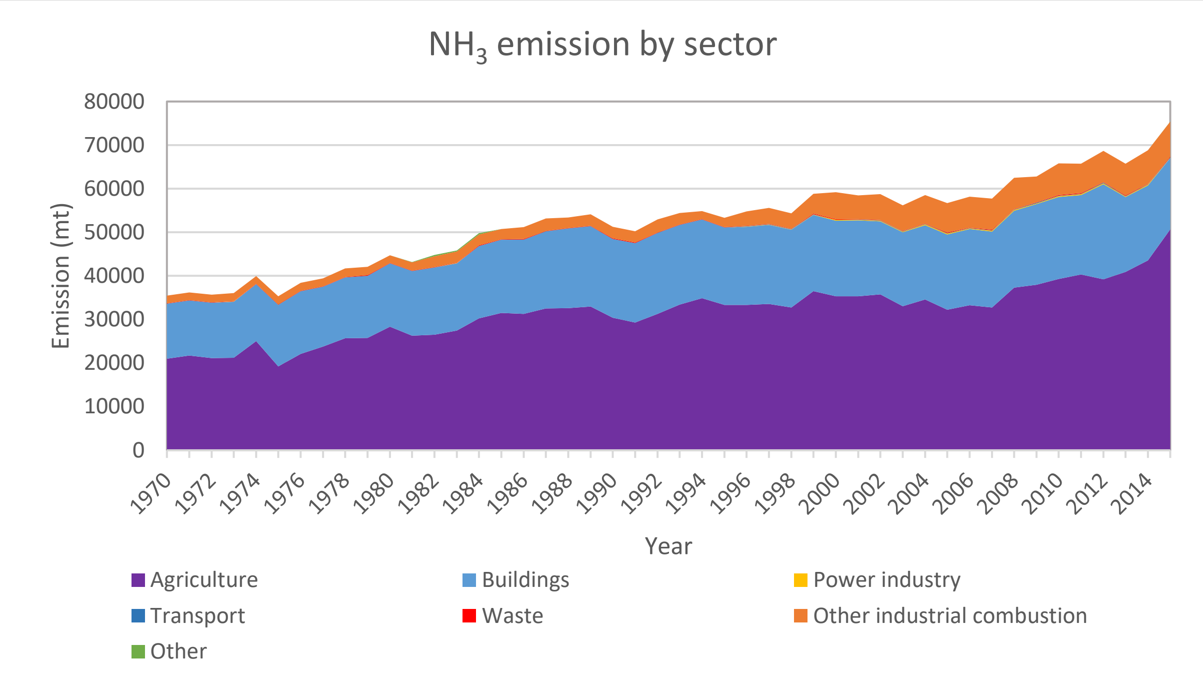


Table 17. Total Ammonia (NH_3) emissions per sector between 2000 and 2015 (Gg per year) and percent change

Main Sector	2000 (Tonnes)	2000 (as a % of total emission)	2015 (Tonnes)	2015 (as a % of total emission)	% change 2000 and 2015
Agriculture	35350.16	60	50673.87	67	43
Buildings	17349.32	29	16363.43	22	-6
Power industry	154.93	< 1	106.48	< 1	-31
Transport	50.97	< 1	99.86	< 1	96
Waste	104.02	< 1	113.91	< 1	10
Other industrial combustion	6187.7	10	8037.93	11	30
Other	0.11	< 1	0.02	< 1	-82
Total N_2O	**59197.21**	100	**75395.5**	100	**27**

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

Nitrogen oxides (NO_x): Emissions of NO_x, poisonous and highly reactive by-products of high-temperature combustion processes, have increased by 43% from 2000 to 2018 in Sri Lanka. The transport sector (53%) has been the major contributor to national NO_x emissions by the year 2018 (Table 18). The next biggest contributor of NO_x is the Power industry (26%). This was followed by Other industrial combustion (15%), Building (6%), and Agriculture (2%). Between 1995 and 2005, there appears to have been a substantial increase in NO_x emissions (Figure 19). Between 2000 and 2018, Transport (76%) and Other industrial combustions (73%), as single sectors, have experienced the highest increase in emissions of NO_x.

Figure 19. The trend in Sri Lanka total NO_x emission by sector per year from 1970 to 2015 Note: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a).

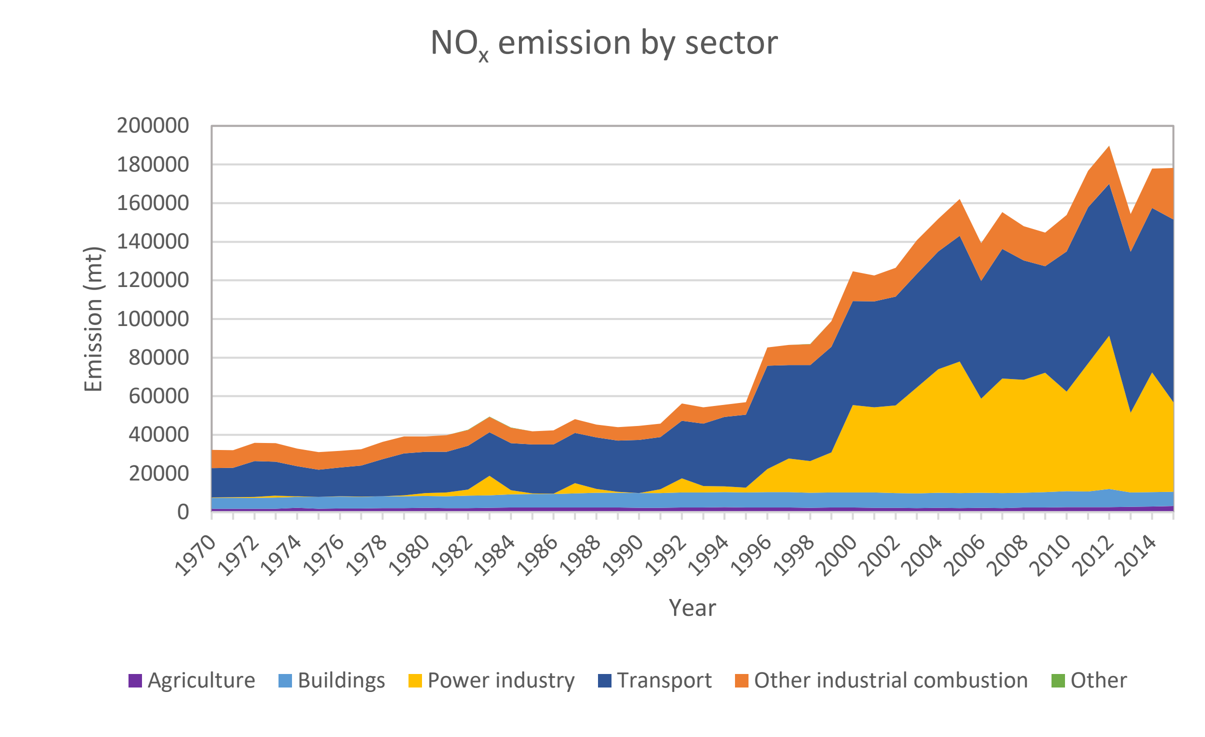


Table 18. Total Nitrogen oxides (NO_x) emissions per sector between 2000 and 2015 (Gg per year) and percent change

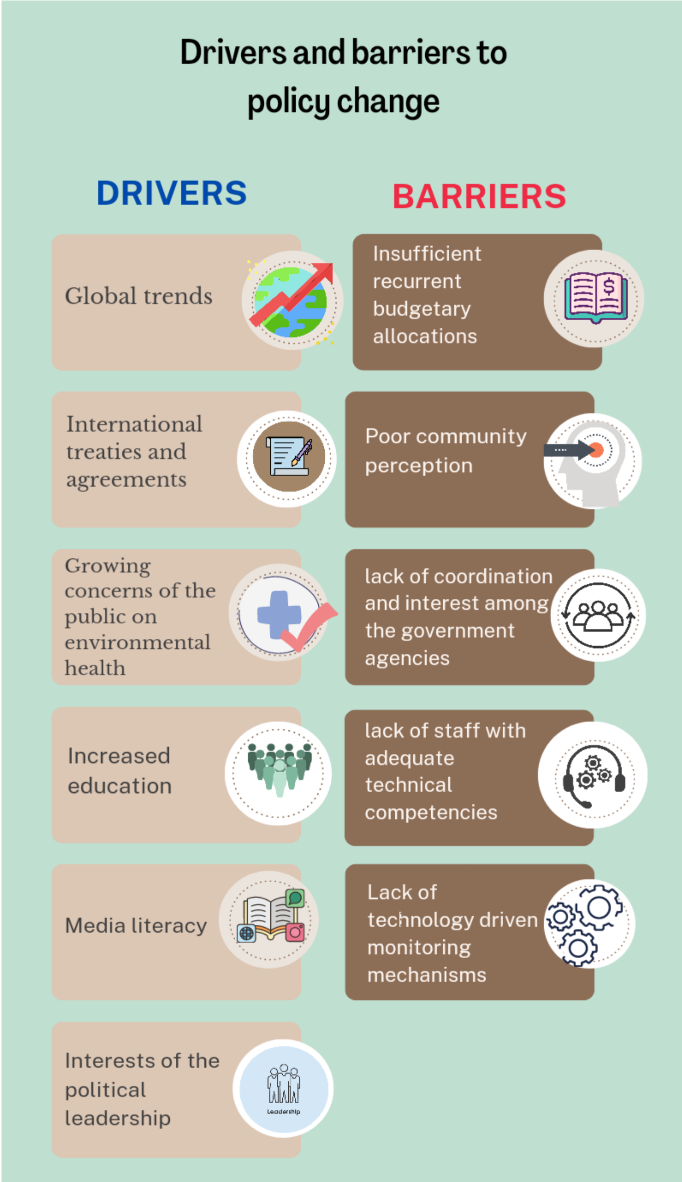
Main Sector	2000 (Tonnes)	2000 (as a % of total emission)	2018 (Tonnes)	2018 (as a % of total emission)	% change 2000 and 2018
Agriculture	2317	2	3140	2	36
Buildings	7862	6	7351	4	-6
Power industry	45251	36	46450	26	3
Transport	53848	43	94562	53	76
Other industrial combustion	15397	12	26683	15	73
Other	1	0	3	0	117
Total N2O	**124676.35**	100	**178187.5**	100	**43**

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

6.3 Analysis of drivers and barriers to policy change

Several key factors could be identified as drivers underpinning N_r related policy establishment and amendment in Sri Lanka. Tangible repercussions of overexploitation and mismanagement of resources (manifested as public health issues, environmental issues, and socio-economic problems), global trends, international treaties and agreements, growing concerns of the public on environmental health, socio-demographic trends (e.g., increased education and media literacy) and interests of the political leadership can be considered as those drivers. As stated in a previous section of this report, particularly there has been a great interest among the recent governments of Sri Lanka (elected to power after the year 2000) to introduce policies proposing or enforcing interventions to control N_r pollution in Sri Lanka.

Although there is a growing context conducive for N_r management policies to emerge in Sri Lanka, there are certain critical barriers and bottlenecks that hinder effective enforcement of policies. Insufficient recurrent budgetary allocations for policy implementation, poor community perception and trust on intents of the policies, lack of coordination and interest among the government agencies to collectively enforce the policies, lack of staff with adequate technical competencies and resources to execute the policies, and lack of technology driven monitoring mechanisms can be listed as some of those common barriers that exist across most of the sectors responsible in N_r pollution.

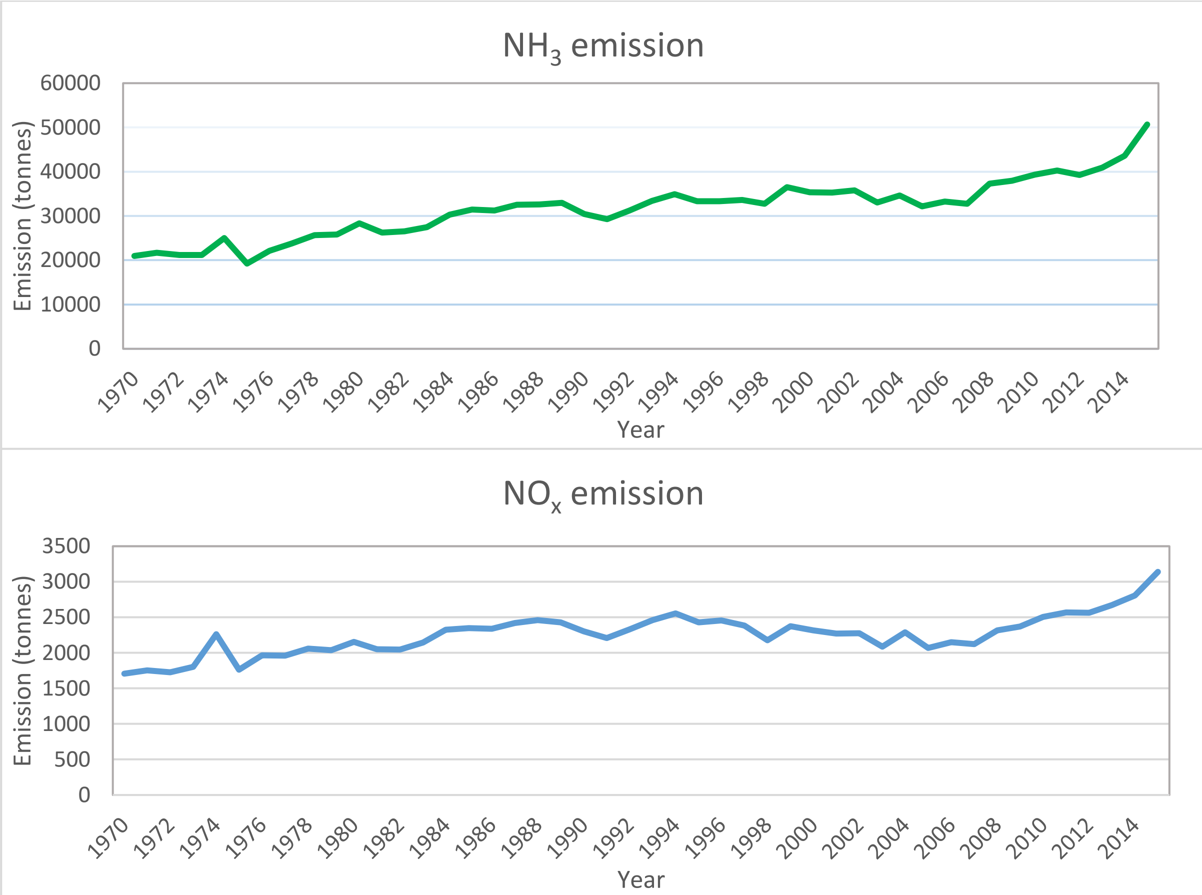


6.3.1 Agriculture

The highest number of N_r related policies was established for the agriculture sector. N_r pollutants released into the environment by the agriculture sector result in depleted air, water and soil quality. The trend of the contributions of agriculture sector for air pollution from 1970 to 2015 is shown in Figure 19, which shows N_r gas emission from agriculture sector has significantly increased over time.

The major drivers underlying the N_r related agriculture sector policies are three-fold. Drivers such as low productivity of crops, absence of a domestic industry for synthetic fertilizer production and slow diffusion of modern agricultural technologies among farmers have given rise to agricultural policies with a negative impact direction (i.e., Paddy lands act, No 1 of 1958 and Tea subsidy act (no 12 of 1958). The set of policies with mixed/ neutral impact direction (e.g., Regulation of fertilizer act, No. 69 of 1988 and National Agriculture Research Policy and Strategy: 2018 – 2027), which accounts for most of the N_r policies developed within the sector, have been developed with a main focus on agricultural productivity while acknowledging the concerns on environmental health. This analysis could observe only a few agricultural policies with an exclusive focus on N_r management (with positive impact direction), e.g., National policy and strategy on cleaner production for Agriculture Sector and Collecting, holding and supplying of shrimp brooders in order to breed brackish-water shrimps (Penaeus Species) regulations no. 2 of 2017.

Figure 19. Trend in N_r gas emission from agriculture sector in Sri Lanka from 1970-2015.
Note: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a); Edgar v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b)



Although there are several agricultural policies with an explicit mandate to control N_r pollution caused by agricultural production, several barriers could constraint the implementation of those policies. Poor coordination among the stakeholders, lack of grassroots level steering mechanisms, knowledge gaps in farming communities and competing social norms could be some of those probable bottlenecks that must be addressed to exploit the full potential of aforementioned policies.

Nitrogen fertilizer use and the subsidy program: Nitrogen fertilizer, which has been the biggest contributor to NH_3 and N_2O emissions in Sri Lanka, is one of the most politically sensitive commodities. Early post-independence governments (elected after gaining independence from the British crown in 1948) had to come up with strong and generous policies to encourage small holding farmers to adopt N_r fertilizer (urea/ ammonium sulphate). As per the historical records, there was strong resistance from the farmers to adopt synthetic fertilizer, even with lucrative incentives (Census of Agriculture, 1962). Eventually, over the next few decades, the fertiliser subsidy program along with other complementary policies that promoted the diffusion of green revolution technologies (i.e., new improved seeds, other agro-chemicals, irrigation and machinery) transformed synthetic N_r fertilizer into an indispensable input in food and plantation crop production in Sri Lanka. Eventually, overconsumption of fertilizer emerged into a pervasive practice in certain agricultural systems. The fertilizer subsidy, which was largely rejected by the farmers in its inception, later turned into a normative right of the Sri Lankan farmers, particularly of those who are engaged in rice farming. During the last few decades, the fertilizer subsidy program gained prominence in much political propaganda as fertilizer turned into a factor that shaped the political terrain of the country. Thus, it grew in size, adding more and more burden to the national economy until the very recent move of the incumbent government to abruptly ban importation of all forms of synthetic fertilizer in 2021. The public unrest that grew into a heated political turmoil following the government's decision to ban synthetic fertilizer compelled the government to lift the ban after a few months.

Fertilizer and other green revolution technologies could support the island nation to attain near self-sufficiency in the staple food crop (i.e., rice) (Wickramasinghe, Samarasinghe and Epasinghe , 2010) and increase the productivity of major export crops (i.e., tea, rubber, coconut and spice crops). However, food security and economic gains realized with synthetic fertilizer have entailed a cost on environment and human health. Further, heavily subsidized N_r fertilizer grew into a national burden as Sri Lanka had to entirely depend on overseas markets for synthetic fertilizer.

Although there had been a few attempts to establish a domestic N_r fertilizer production industry in the country, those attempts could not be fruitful due to various bottlenecks. The State Fertilizer Manufacturing Corporation (SFMC), which was established under the State Industrial Corporation Act of 1973, once set up a urea factory in Sapugaskanda. The naphtha-based urea plant could only continue its production for three years until it was completely shut down in 1985. By that time, the government had observed that it could earn a better profit from selling naphtha to other countries rather than pumping it into urea production.

In the absence of a domestic industry to meet the national demand for N_r fertilizer, the policies introduced to regulate the import and use of N_r fertilizer in Sri Lanka have evolved on a path shaped by competing interests originated out of global pressures, national goals and political motives. The national fertilizer subsidy program, which has been by far the most influential formal institution regulating N_r use in the agriculture sector, has largely evolved without a long term vision for sustainability. Largely, the subsidy program has grown based on the national interests to achieve food security and increased earnings from agricultural exports amplified by the political interests of the ruling governments to hold the rural voter bases. However, in certain instances, the scheme underwent revisions in favour of the health of the economy and the environmental quality but against the will of the farmers. The international donor agencies have also played a role in such decisions of the government to revise the subsidy scheme. One such instance is the abolition of the subsidy in 1990 due to a loan agreement with the World Bank and the IMF (Abeygunawardena, 2014). However, the government elected in 1994 reintroduced the scheme which was almost 0.1 percent of the national GDP (Ekanayake, 2006).

The drastic and improper revisions introduced to the subsidy program have resulted at times in public unrest, food shortages as well as mis-consumption of fertilizer. A policy environment that can smoothly reduce the N_r fertilizer use in Sri Lanka while maintaining the yields necessary to feed the expanding population and meet the economic goals is a critical necessity (Jeevikka et al., 2021).

Figure 20: The chronology of the fertilizer subsidy program in Sri Lanka

Year	Specification
1951	• A fertilizer subsidy program for paddy was introduced
1956	• A fertilizer subsidy program for coconut was introduced
1962	• The subsidy program was introduced for all crops with a major concern on rice • All the paddy cultivators were given with the subsidy (previously, only the farmers who were members of Co-operative societies, farmers obtaining their requirements through Cultivation Committees and the farmers who could make direct cash purchase from the Agriculture Department had access to the subsidy) • Different fertilizer types were subsidized at different rates and the subsidy level

	varied according to the crop type
1971	• Importation of fertilizer became a monopoly of the Ceylon Fertilizer Corporation, and importation of fertilizer by the private sector was banned.
1975	• A uniform subsidy for all crops was introduced to prevent unauthorized leakage of fertilizer between the sub- sectors.
1977	• Private sector companies were allowed to import fertilizer
1978	• The Subsidy was restructured to introduce a uniform rate (50%*) for all fertilizer types
1979	• The Subsidy was restructured and increased (Urea: 85% and other: 75%)
1981	• The Subsidy was decreased due to increased world market prices (Urea: 65%, MOP: 65% & TSP: 40%)
1983	• Regardless of the market fluctuations, government maintained a fixed price for fertilizer
1988	• The Subsidy was decreased due to world market pressure and subsidy for SA and Rock Phosphate was eliminated
1990	• The subsidy was completely removed in accordance with a loan agreement with the World Bank and the IMF
1994	• The subsidy was reintroduced for Urea, SA, MOP & TSP** at a fixed price of 350 LKR for 50 Kg bag.
1996	• The subsidy for SA was eliminated • The fixed price was revised to 600 LKR for 50 Kg bag.
1997	• The subsidy was limited to Urea • The fixed price was reduced to 350 LKR for 50 Kg bag.
2002	• A fixed sum of subsidy was given to Urea importers and the retail prices fluctuated according to the world market prices.
2005	• The subsidy was restricted to rice and small farmers operating less than 5 acres of land. • The scheme was reintroduced for other straight fertilizer forms (MOP and TSP) • Fixed the retail price of fertilizer at 550 LKR for 50 Kg bag.
2006	• The subsidy was extended to small holding (>5 Ac) plantation sector. • The fixed price was reduced to 350 LKR for 50 Kg bag.
2009	• The subsidy program was coupled with a paddy procurement program. This required farmers to supply a portion of their harvest to the government at a pre-determined price below the market price.
2011	• The subsidy was extended to other subsidiary food crops.
2016	• Instead of subsidized price on fertilizer, farmers were granted financial assistance to purchase any fertilizer of their choice from the open market or decide on other alternatives (e.g., invest in organic farming) • Paddy farmers received a maximum financial assistance of Rs.50, 000 for both seasons (maximum Rs.25, 000 for 2 hectares for a single season). • Potato, onion, chilli, soya bean and maize farmers received a cash subsidy of maximum Rs. 10,000 per hectare per year. • The maximum retail price of a 50 kg bag of straight fertilizer - Urea, TSP and MOP - was Rs. 2,500.
2018	• Reinstated the revoked policy decision to provide fertilizer at a subsidized price. • Urea, TSP and MOP – are issued at Rs. 500 per 50 kg as straight fertilizer for paddy and at Rs. 1,000 per 50 kg as straight fertilizer for other crops and at Rs. 1,150 per 50 kg for fertilizer mixtures • Fertilizers are issued on the basis of recommendations given by the Department of Agriculture. Therefore, the quantities are issued according to the land extent and

	respective fertilizer recommendation.
2020	• For the first time in history, fertilizer was provided free of charge for paddy up to a cultivation area of 5 acres
2021 May	• Imports & Exports (Control) Regulation No 07 of 2021 was adopted on May 6, 2021, prohibiting the importing of chemical fertilizers, insecticides, and herbicides
2021 July	• The import restriction was replaced with an import license requirement for chemical fertilizers

* The percentage denotes the rate of subsidy as a percent of the cost, insurance and freight price.
** Straight fertilizer forms: MOP – Muriate of Potash, SA – Sulphate of Ammonia, TSP – Triple Super Phosphate
Sources: Bansil (1971), Ekanayake (2006); Weerahewa et al. (2010); Department of Census and statistics (2013); Abeygunawardane (2014); Herath et al. (2013)

6.3.2 Energy

Sri Lanka uses both renewable and non-renewable sources for energy generation. Sri Lanka mainly depends on non-renewable sources, such as fossil fuel and coal, to generate energy for domestic consumption (Figure 21). Hydropower, solar power, and wind power are the main renewable energy sources. The total energy production for the year 2019 was 15,922.39 GWh and the contribution from non-renewable sources was 65% of the total production (Figure 21). The Ceylon Electricity Board (CEB), the main electricity producer in Sri Lanka, generated 71% of the energy in year 2019, whereas non-renewable sources accounted for 66% of the total energy generated by the CEB in the same year. As Figure 21 illustrates, coal based energy production started in the year 2011, and the contribution of coal to energy generation has exponentially increased ever since. Meanwhile, in compliance with the global trend of transitioning to cleaner energy production through renewable energy sources, Sri Lanka has shown a promising interest to introduce energy produced through renewable sources to the national grid over the last decade (figure 21).

Figure 21. On-grid installed electrical capacity (in megawatts) and on-grid electrical production (in gigawatt-hours) of Sri Lanka, from 2000 to 2018 . Source: Abubakr, R (2016)

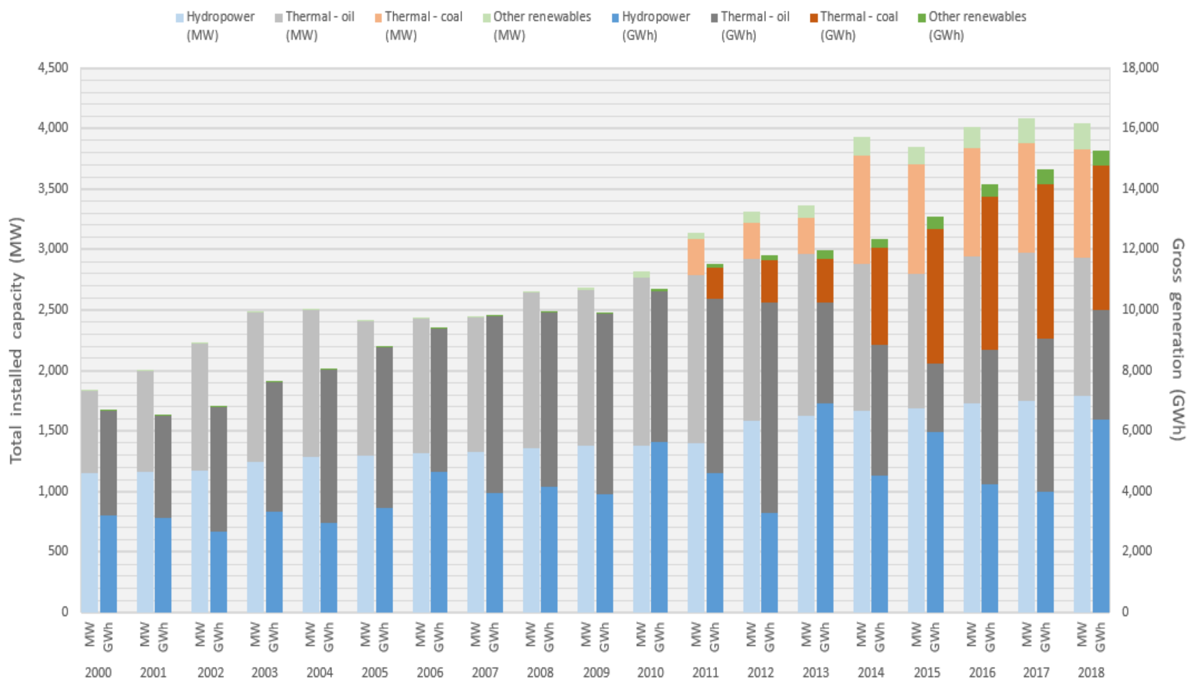
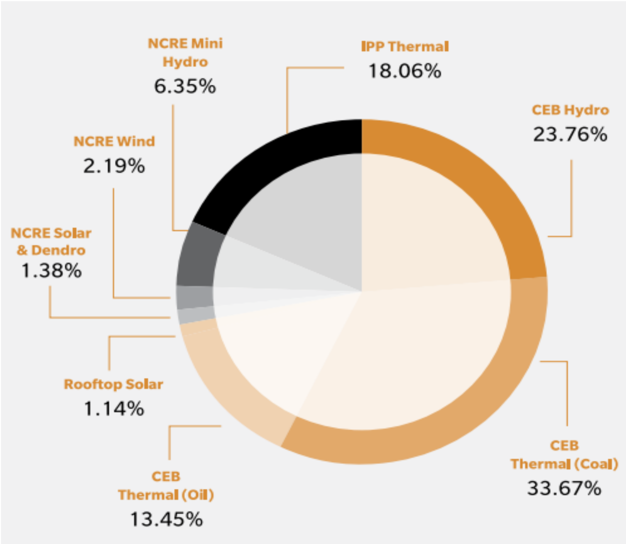
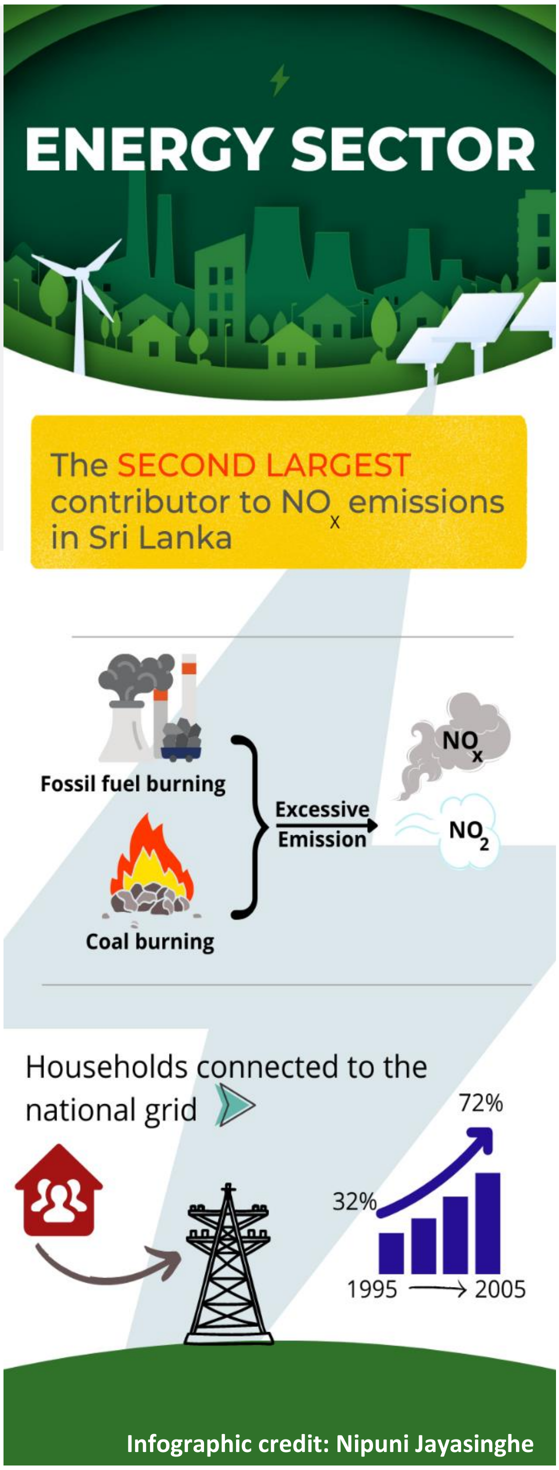


Figure 22. Contribution of different energy sources to electricity production by CEB in 2019.
Source: CEB annual report, 2019

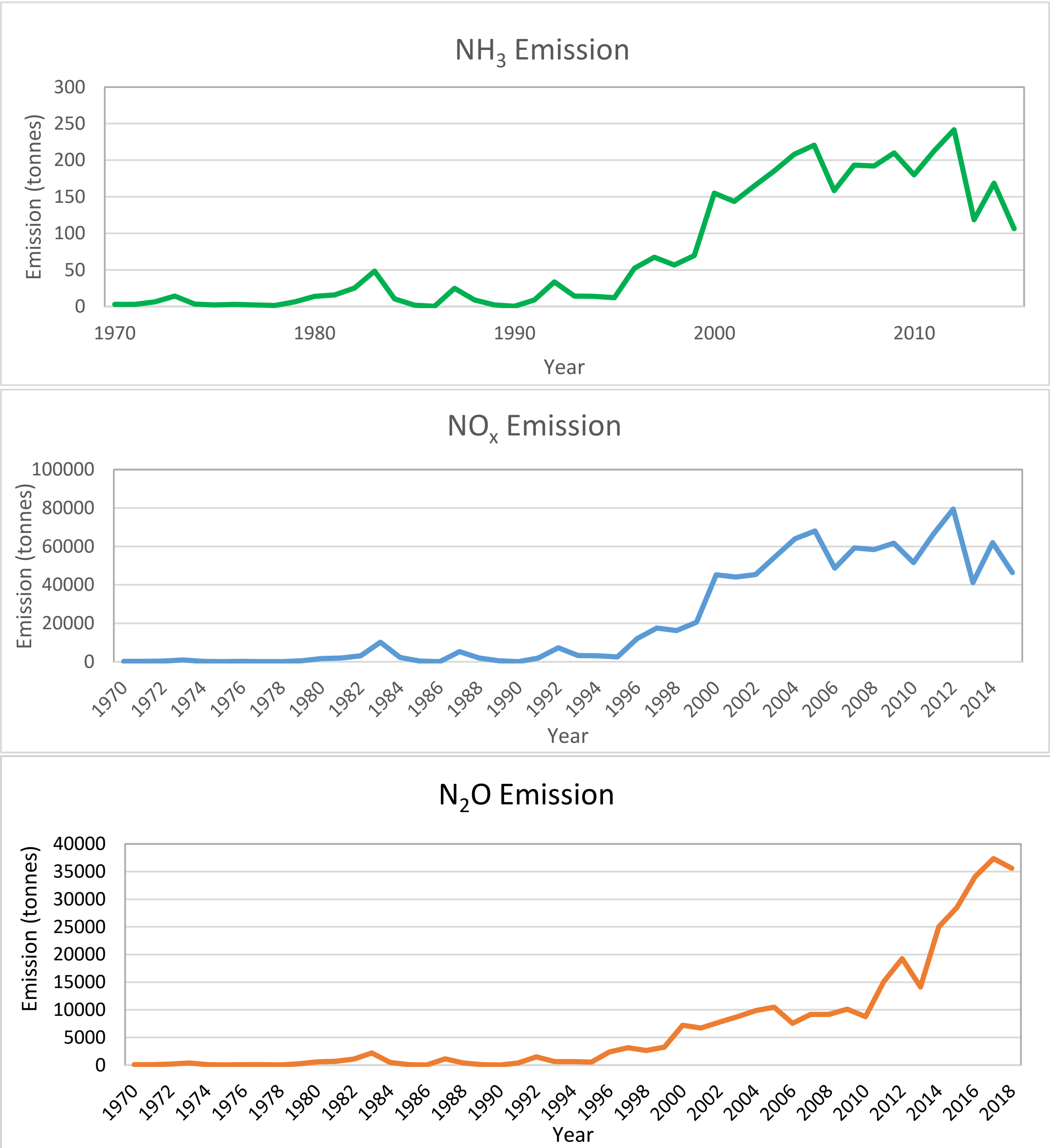




After the transport sector, the second largest contributor to NO_x emissions in Sri Lanka is the energy sector. Fossil fuel and coal burning for energy generation result in excessive emissions of NO_2 and other NO_x gases. The trend of the contribution of the energy sector to air pollution from 1970 to 2015 is shown in Figure 23. There is a sudden rise in emissions of all the three major forms of reactive N_r due to energy production from 1995 till 2005 (Figure 23). The past data shows that households connected to the national grid increased from 32% in 1995 to an unprecedented rate of 72% by 2005. The demand for energy by the industrial sector has also highly increased within the same period. In accordance with the increased demand for electricity, during the aforementioned period, Sri Lanka's total installed capacity and production demand has increased by 895 MW and 2600 GW/h respectively. Fuel-based energy sources have contributed to much of the above increased capacities.

A few policies have been established to curb the impact of the energy sector on air quality (e.g., 'National Environmental (Stationary Sources Emission Control) Regulations, No. 01 of 2019'). The establishment of the Sustainable Energy Authority (SEA) is another commendable move by the Sri Lankan government to promote renewable energy for clean energy production. The SEA is vested with power to execute the Sri Lankan Sustainable Energy Authority Act, No. 35 of 2007. One of the major mandates of the SEA is to enable Sri Lanka to transition to cleaner and sustainable energy solutions.

Figure 23. The trend in N_r gas emission from the energy sector in Sri Lanka from 1970-2015.
Note: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a); EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b)

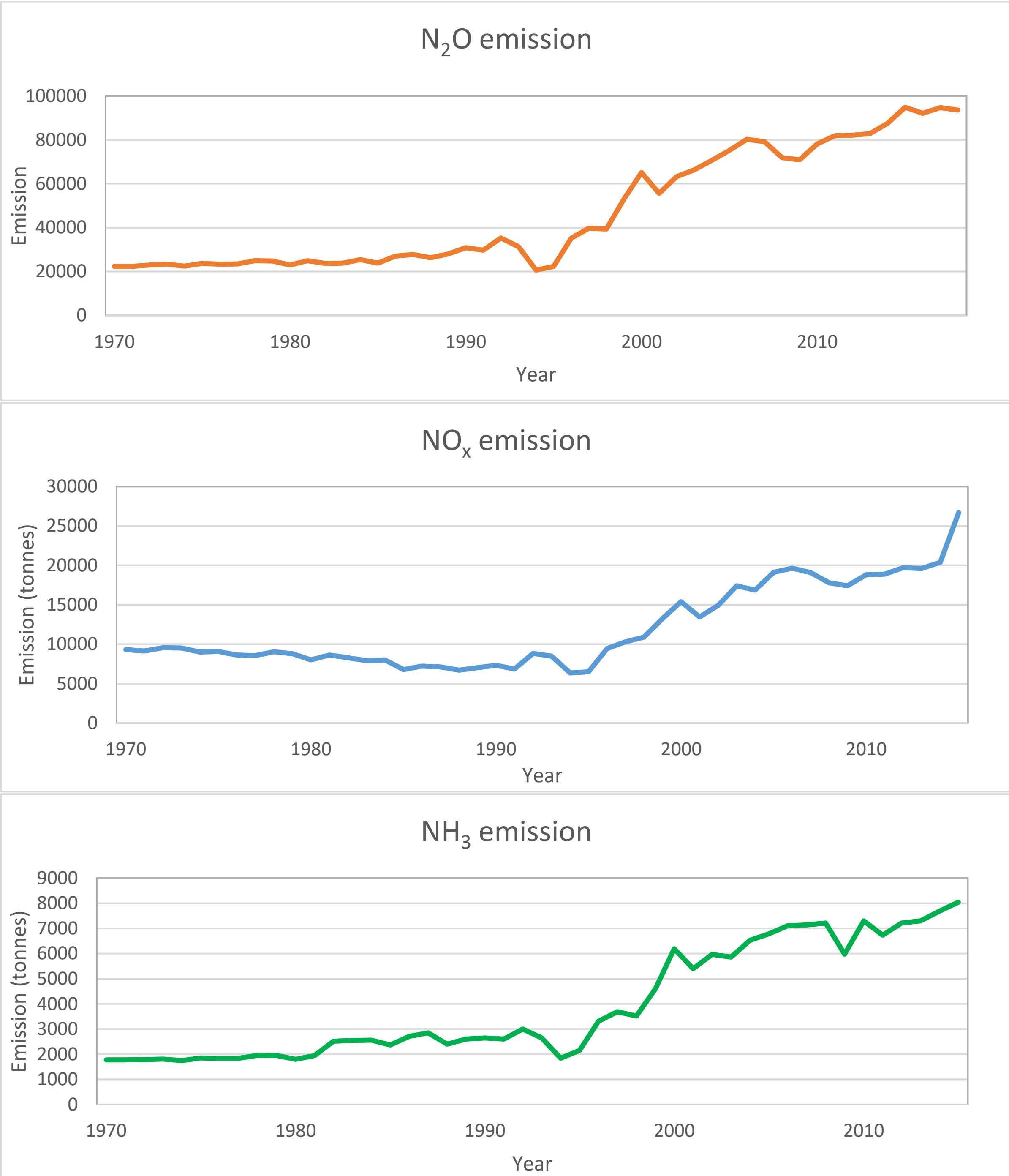


6.3.3 Industry

The Industrial sector in Sri Lanka emits N_r pollutants to all forms of sinks, especially air, water, and ecosystem. The industrial sector releases a great amount of NO_x to the atmosphere through the internal combustion of engines and machinery. Figure 24 illustrates reactive Nr gas emissions resulting from the industrial sector in Sri Lanka from 1970 to 2015. As the figure illustrates, there is an increasing trend of NO_x, N_2O and NH_3 resulting from the industrial sector since the mid-1990s. Particularly, NO_x emissions resulted from industrial combustions has increased by 73% over a period of eight years from 2000 to 2018.

Figure 24. The trend in N_r gas emission from the industrial sector in Sri Lanka from 1970-2015

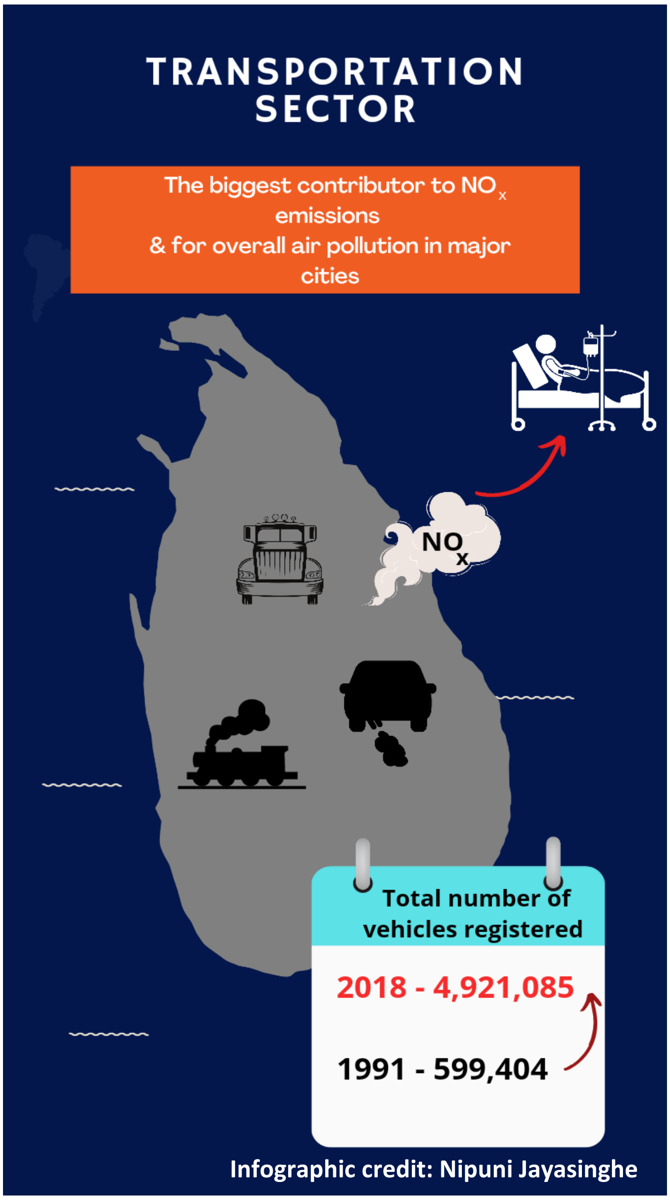
Note: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a); EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b)



A few recent policies, such as the National Environmental (prohibition of ozone depleting substances) regulations no. 01 2003 (amended in 2008) and National Policy and Strategy For Cleaner Production (2005), reflect the recent interest of the government to curb pollution caused by the industrial sector. There is a developing trend among the media, environmental activists and certain segments of the public in lobbying for action against the environmental issues caused by pollutants released by manufacturing firms. This activism, as long as it remains non-violent and informative, is a positive factor that can influence the government to introduce more policies with a positive impact direction related to N_r management. While being vigilant and concerned about the environment, the Sri Lankan government has a mandate to develop its economy mainly by strengthening the industrial sector. Thus, the requirement for policies that can promote industrial practices while complying with the global standards to maintain N_r emissions at acceptable levels is a necessity.

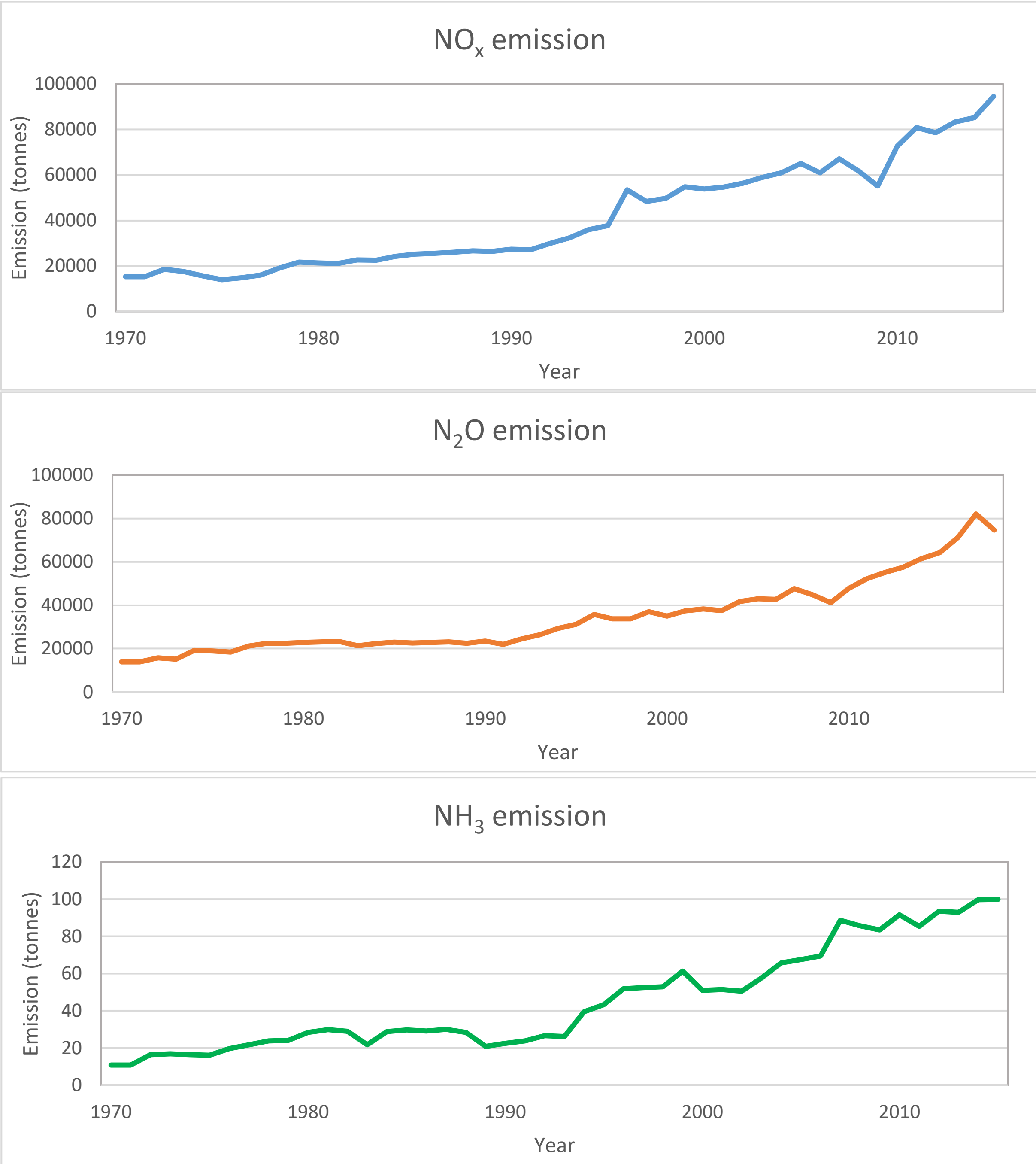
6.3.4 Transportation

Transportation is another main sector that contributes to the accumulation of reactive N_r in the atmosphere in Sri Lanka. Internal combustion of vehicle engines produces NO_x gases that can be harmful to human health. The contribution of the transport sector to air pollution from 1970 to 2015 is illustrated in Figure 25. The transport sector accounted for the highest portion of NO_x emitted into the air in 2018 (Table 18). These figures are well explained by the increase in number of vehicles in the country over the last two decades. The total number of vehicles registered in Sri Lanka by the year 1991 was 599,404. This rose to a staggering number of 4,921,085 registered vehicles by the year 2018 (Illeperuma, 2020).



To curb the air pollution caused by the transport sector a few direct policy measures have been introduced over the recent past, e.g., National Environmental (air, fuel and vehicle importation standards) Regulations No. 01 2003. The transport sector is the biggest contributor to NO_x emissions and to overall air pollution in major cities (Illeperuma, 2020), so more policy interventions by the government are needed to curb the excessive emission of N_r gases by vehicles given the increasing N_r emission trends from this sector. The government must also set up a conducive environment for the relevant authorities to fully exploit the policy instruments needed to meet the policy objectives. Financial limitations, lack of a good monitoring system, and absence of a good public transportation system may hinder such policies in achieving their intended outcomes.

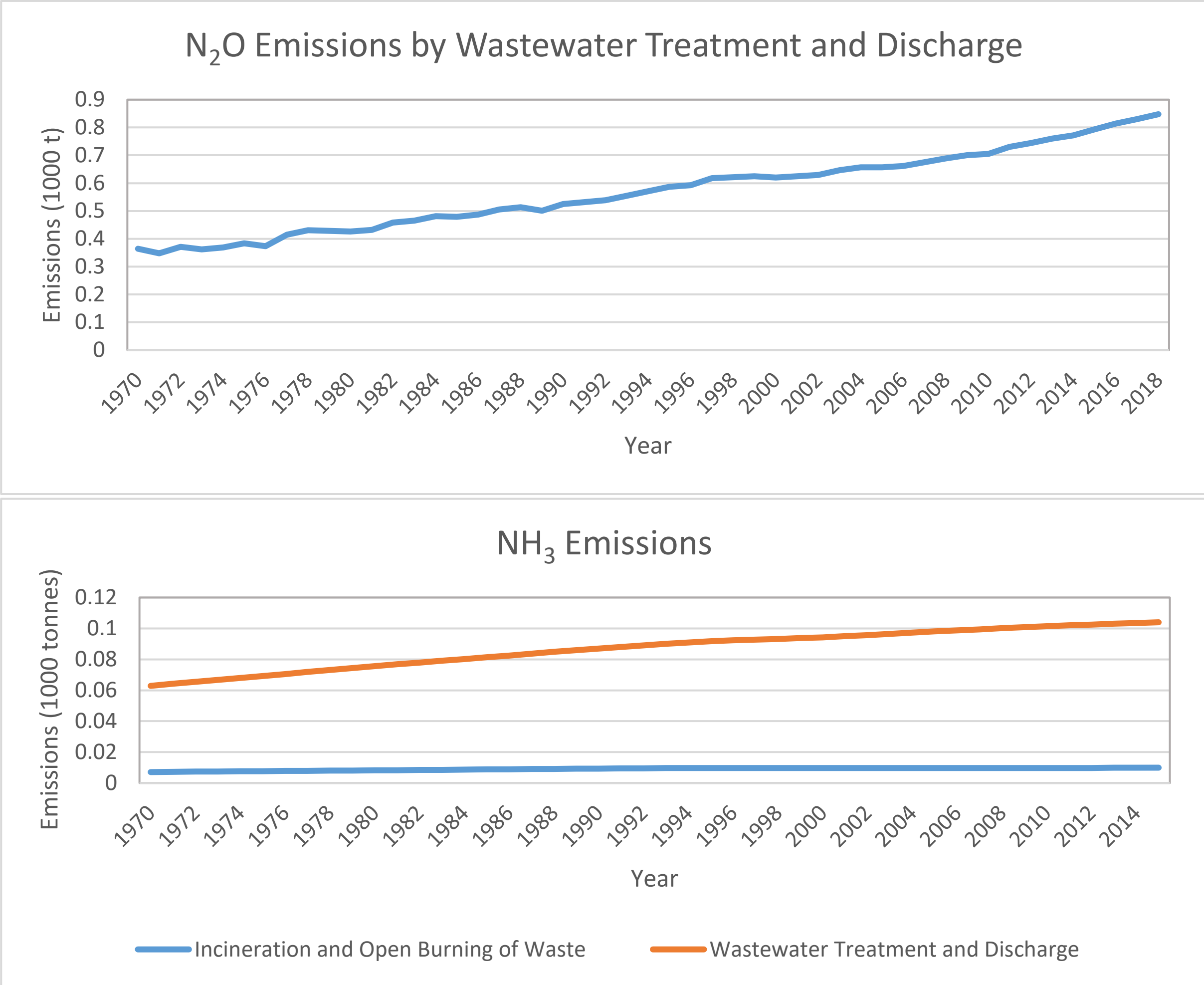
Figure 25. The trend in N_r gas emission from the Transportation sector in Sri Lanka from 1970-2015
Note: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a); EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b)



6.3.5 Waste

Waste, particularly domestic and industrial waste, has been another significant source of N_r pollution in Sri Lanka. Although the available date is insufficient to provide a complete view on the actual contribution of the waste sector to reactive N_r emissions in Sri Lanka, certain studies could provide an insight into the increased nitrogen pollution resulting from solid and effluent waste generated from domestic and industrial sectors.

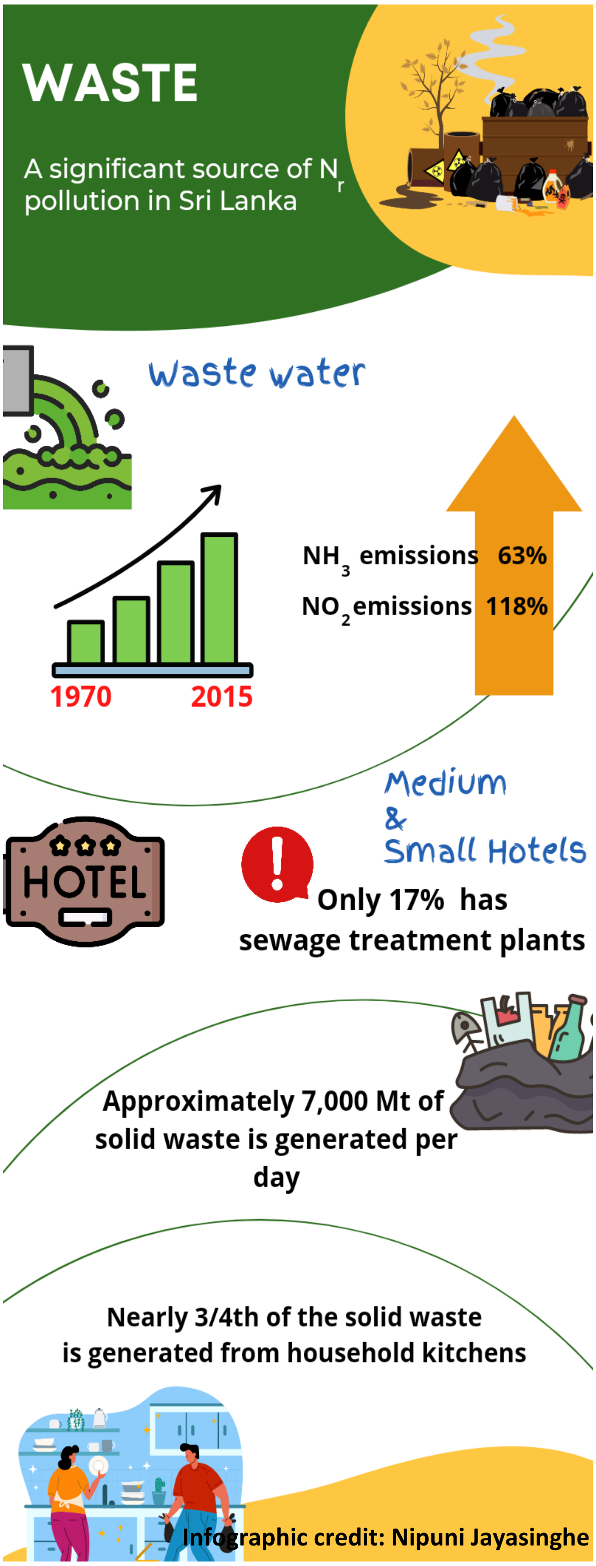
Figure 26. The trend in N_r gas emission from the Waste sector in Sri Lanka from 1970-2015 Note: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a); EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b)



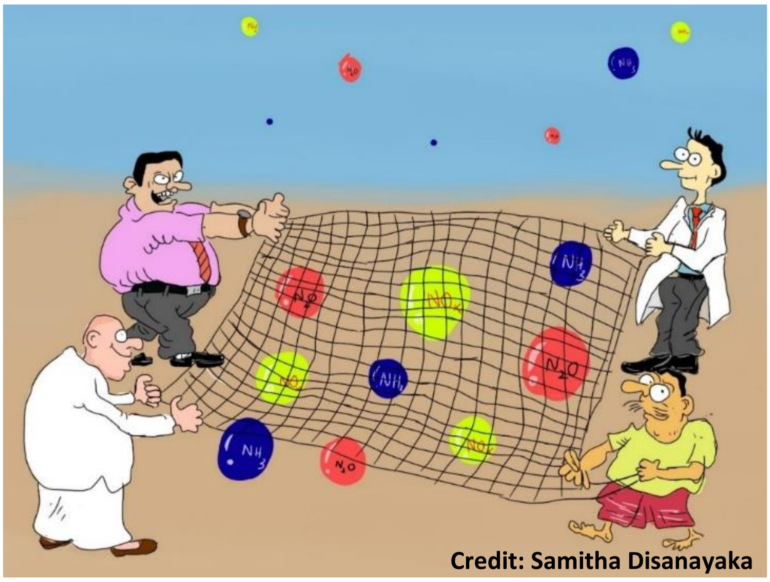
According to the EDGAR database (2019), over the period from 1970 to 2015, NH_3 and N_2O emissions resulting from waste water increased by 63% and 118% respectively (Figure 26). Sieh et al. (2021) report that the Sri Lankan coastal lagoons are prone to eutrophication and hypoxic events due to contamination by anthropogenic inputs of nitrogen and phosphorus wastes. The same report, with reference to Negomobo lagoon, shows how solid domestic and industrial waste, sewage discharged from tourists hotels and effluents discharged from aquaculture farms and other surrounding industries can significantly contribute to the pollution of coastal lagoons with nitrogen and other anthropogenic pollutants. It is apparent that population growth, rising levels of consumption and emerging industries have contributed to much of the nitrogen pollution caused by improperly managed waste disposal. For example, it is reported that only 17% of the medium and small hotels, which play a major role in the booming tourism industry in Sri Lanka, have sewage treatment plants (Switch Asia, Greening Sri Lanka Hotels Project, 2013 as cited in BOBLME, 2013).

Solid waste management has also been a challenging task for Sri Lanka. Approximately 7,000 Mt of solid waste is generated in Sri Lanka per day (Dharmasiri, 2019). According to JAICA (2016), waste generated per day in Sri Lanka had increased by 68% alone within the decade from 1999 to 2009. Nearly three forth of the solid waste is generated from household kitchens (WACS, 2014) whereas much of the collected solid waste ends up in landfills (Bandara, 2018).

To minimize the impact of waste sector on environmental quality, a number of policies have been introduced by the Sri Lankan government, particularly to manage waste generated by industries and municipal residents. Most of the policies have been introduced within the last decade in which the Ministry of Environmental has been vested with much authority to implement waste related policies. National Environmental (Protection and Quality) Regulations (No. 1 of 2008, National Policy on Waste Management, 2019 and Marine Environmental Protection (Issuance of Permits for Dumping at Sea) Regulations No. of 2013 are some of the notable policy interventions with a direct and high impact on controlling N_r pollution.



7 Stakeholder Overview



Credit: Samitha Disanayaka

Stakeholders in this report are defined as individuals or groups who have an interest and/or potential influence on N_r management. This includes a wide range of actors due to the multiple sector sources of N_r waste, along with the human and environmental impacts it can have. Table 19 gives a preliminary overview into some of the main groups who may have a role in improving and addressing N_r management and influencing policy. This includes government groups as well as non-government groups. The degree to which all the stakeholders, including politicians, bureaucrats, businessmen, researchers and the public, act in a co-ordinated and complementary manner will determine how well a nation could lay a protective policy net to prevent reactive N_r compounds from polluting the country's air, water, soil and ecosystems. SANH will continue to develop a better understanding of the nitrogen–relevant stakeholders over the course of the project.

Table 19. Preliminary stakeholder overview

Main groups	
Government	Three branches of government: Executive, Legislature and Judiciary. Ministries (e.g. Ministry of Environment, Ministry of Agriculture). Centres and Organizations (e.g., Disaster Management Centre (DMC), National Building Research Organization (NBRO)) Authorities (e.g., Central Environmental Authority (CEA), Maheweli Development Authority, Marine Environmental Protection Authority (MEPA), Urban Development Authority (UDA)) Institutes (e.g., Sri Lanka Standards Institute (SLSI) Councils and Commissions (e.g., Sri Lanka Council for Agricultural Research Policy(CARP), Public Utilities Commission of Sri Lanka (PUCSL))
Sub-national government	Provincial governors Provincial councils District secretariats Divisional secretariats Provincial councils Municipal councils Urban councils

	Pradeshiya sabha
International organisations/agencies/donors	United Nations (UNDP, UNEP, FAO, United Nations World Food Programme (WFP) Development banks (World Bank, Asian Development Bank) Donor countries development aid institutes (USAID, GIZ, JICA)
Regional partnerships	South Asian Association for Regional Cooperation (SAARC) South Asia Co-operative Environment Programme (SACEP)
Non-Government Organisations (NGOs)	Environment Foundation Friends of the earth international Centre for environmental justice Federation of environmental organizations
Research and universities	State Universities (e.g., University of Peradeniya, University of Colombo, University of Sri Jayawardhanapura) Crop Research Institutes (e.g., Rice research institute, Tea research institute, Rubber research institute, Coconut research institute). Other research institutes (e.g., Industrial Technology Institute, Hector Kobbekaduwa Agrarian Research and Training Institute, National Institute of Fundamental Studies)
Private sector	Fertilizer producing and distribution companies (e.g., CIC Holdings, A. Lankem Ceylon PLC.) Environmental quality management companies (e.g., Laughs ECO Sri Limited, Control Union certifications Ltd.)

There are several ministries that are assumed to be key actors when it comes to N_r management and policy such as those responsible for agriculture, energy, transport and the environment. There are Departments, Authorities, Corporations, Institutes, Councils, Corporations and Boards and major Companies established under each ministry directly and indirectly responsible in N_r management and policy related processes. Table 20 contains the preliminary list of relevant ministries and affiliated entities.

Table 20. The preliminary list of relevant ministries and affiliated entities
Note: Institutes in italic do not have a nation-wide coverage or scope, whereas their scope is limited to a particular geographic unit or a specific production process.

Ministry of Agriculture	• Department of Agriculture • Department of Export Agriculture • Agricultural & Agrarian Insurance Board
State Ministry of Paddy and Grain, Organic Food, Vegetables, Fruits, Chilies, Onion and Potato Cultivation Promotion, Seed Production and Advanced Technology Agriculture	• Divisional Economic Centres • Paddy Marketing Board • Department of Agrarian Development • Sri Lanka Council for Agricultural Research Policy (CARP) • Institute of Post-harvest Technology • Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI)

State Ministry of Production and Supply of Fertilizer and Regulation of Chemical Fertilizer and Insecticide Use	• Pulses and Grain Research and Production Authority • Ceylon Fertilizer Co. Ltd • National Fertilizer Secretariat • Colombo Commercial Fertilizer Co. Ltd • National Agricultural Diversification and Settlement Authority • National Hunger Eradication Campaign Board of Sri Lanka
State Ministry of Livestock, Farm Promotion and Dairy and Egg Related Industries	• Department of Animal Production and Health • National Livestock Development Board and affiliated companies • *Mahaweli Livestock Enterprises Ltd.* • *Milco (Pvt) Ltd*.
Ministry of Energy	• Ceylon Petroleum Corporation • Ceylon Petroleum Storage Terminal • Petroleum Resource Development Secretariat
Ministry of Power	• Ceylon Electricity Board • Lanka Electricity Company (Pvt) Ltd • Sri Lanka Sustainable Energy Authority • Sri Lanka Atomic Energy Board • Lanka Electricity Company (Pvt) Ltd • Lanka Coal Company (Pvt) Ltd
Ministry of Wildlife and Forest Conservation	• Department of Wildlife Conservation • Department of Forest Conservation • State Timber Corporation • Department of National Zoological Gardens
Ministry of Environment	• Geological Survey and Mines Bureau • Central Environmental Authority • GSMB Technical Services • Sri Lanka Climate Fund
Ministry of Urban Development and Housing/ State Ministry of Urban Development Waste Disposal and Community Cleanliness	• Urban Development Authority • Urban Settlement Development Authority • Condominium Management Authority
Ministry of Lands	• Survey Department • Land Title Settlement Department • Land Commissioner General's Department • Land use Policy Planning Department • Land use Policy Planning Department
Ministry of Plantation/ State Minister of Coconut, Kithul and Palmyrah Cultivation Promotion/ State Minister of Company Estate Reforms Tea and Rubber Estate Related Crops/ State Minister of Development of Minor Crops	• Tea, Rubber and Coconut Plantation Fragmentation Control Board • Sri Lanka Tea Board • Tea Research Institute of Sri Lanka • Tea Small Holdings Development Authority • State Plantation Corporation • National Institute of Plantations Management • Rubber Development Department

	• Rubber Research Institute of Sri Lanka • Coconut Cultivation Board • Coconut Research Institute • Coconut Development Authority • Sri Lanka Cashew Corporation • Sugarcane Research Institute • Spices and Allied Products Marketing Board • Palmyrah Development Board • *Kalubowitiyana Tea Factory Ltd.* • *Elkaduwa Plantation Ltd.* • *Sri Lanka Rubber Manufacturing Export Corporation Ltd.* • *Kurunegala Plantation Company Ltd.* • *Chilaw Plantation Company Ltd.* • *Lanka Sugar Company (Pvt) Ltd.* • *Kantale Sugar Company Ltd.* • *Galoya Plantation (Pvt.) Company*
Ministry of Irrigation/ State Ministry of Tanks, Reservoirs and Irrigation Development related to Rural Paddy Fields/ State Ministry of Mahaweli Zones Development	• Irrigation department • Mahaweli Authority of Sri Lanka • Irrigation Management Division • Kothmale International Training Institute
Ministry of Water Supply/ State Minister of Rural and Regional Drinking Water Supply Project Development	• National Water Supply and Drainage Board
Ministry of Industries	• Ceylon Industrial Development Board • Sri Lanka Institute of Textile and Apparels • Department of Textile Industries • Sri Lanka Cement Corporation • National Gem and Jewellery Authority • Gem and Jewellery Research Institute • *Kahatagaha Graphite Ltd.* • *Bogala Graphite Lanka Ltd.* • *Lanka Ashok Leyland Ltd.* • *Lanka Textile Mills Emporium Ltd.* • *Lanka Salusala Ltd.* • *National Paper Corporation Ltd* • *Lanka Mineral Sands Company* • *Paranthan Chemicals Ltd.* • *Lanka phosphate Company Ltd.* • *Lanka Ceramics Corporation* • *Kahagolla Engineering Services Company Ltd. (KESCO)* • *BCC (Pvt) Ltd.* • *Palmyrah Development Ltd.* • *Manthai Salt Ltd.* • *Elephant Pass Saltern Ltd.*

Ministry of Health	• Goverment Hospital in Sri Lanka • Provincial Departments of Health Services • Regional Departments of Health Services • *Nurses Training Schools*
Ministry of Transport	• Sri Lanka Railways • Department of Motor Traffic • National Transport Commission • Sri Lanka Transport Board • *National Transport Medical Institute* • *Lakdiva Engineering Company (Pvt) Ltd* • *National Council for Road Safety*
Ministry of Fisheries	• Department of Fisheries & Aquatic Resources (DFAR) • National Aquatic Resources Research and Development Agency (NARA) • National Aquaculture Development Authority (NAQDA) • Ceylon Fisheries Corporation (CFC) • Ceylon Fishery Harbours Corporation (CFHC) • National Fisheries Federation • *Cey-nor Foundation Ltd* • *Northsea Ltd.* • *State Fish Market Complex – Peliyagoda*
Ministry of Ports and Shipping	• Merchant Shipping Secretariat • Sri Lanka Ports Authority • *Ceylon Shipping Corporations Ltd.*

Ministries that may also be relevant to $N_{r,}$ but not directly, 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 Finance
- Ministry of Public Services, Provincial Councils and Local Government
- Ministry of Defence
- Ministry of Tourism
- Ministry of Education

Apart from the Ministries and line agencies, Presidential Task Forces appointed by the executive president (e.g., Presidential Task Force for Green Agriculture, Presidential Task Force for the creation of a Green Socio- economy with Sustainable Solutions for Climate Changes) are also vested with power to create a significant impact on N_r management efforts of the government.

Ministerial Consultative committees (e.g., Ministerial consultative committee on Energy, Ministerial consultative committee on Environment) are formed from time to time to discuss matters related to specific subjects (sectors). Each Ministerial Consultative Committee is chaired by the Cabinet Minister in charge of the relevant subject. The other appointed members of a ministerial committee would be comprised of the State Minister, the Deputy Minister and five other Members of Parliament.

8 Conclusion and Recommendations

For Sri Lanka, 115 directly and indirect nitrogen–related policies, were collected, contributing to 12% of the SANH South Asia policy database. All nitrogen-related policies collected were classified based on certain characteristics. Classifications include: environmental sink; 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 Sri Lanka, there were 178 classifications from the 115 policies, since 42 policies (37%) had more than one policy type identified. 'Framework' policies were the most common policy type (57%). Sector wise the most common classification was for "multiple" sectors at 32%. This is an advantageous policy characteristic indicating and understanding that multiple sectors have roles to play in N_r management. Agriculture oriented policies were also fairly common (15%) compared to other single sector focused policies.

For environmental sinks, the most common classification was where 'multiple' had been included in the policy text (30%). This could be regarded as a favourable policy characteristic, indicating that N_r environmental impacts have been considered. The most common single sink orientated policies were for Ecosystem (17%) followed by Water (10%). Policies classified as having low relevance and/or low impact scope were omitted (7 policies, 6%), leaving 108 policies that are of medium-high impact and relevance and are 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 should not be considered as irrelevant and via amendments could be better adapted to mitigate N_r waste.

Over half of 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 (33%), indicate to varying degrees dual goals for economic development and the environment. Policies with a potentially negative impact direction (4%), i.e., those that risk promoting N_r waste, were small in number. 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. From Sri Lanka there are 9 policies (8%) that hit all of these criteria.

There is a clear surge of N_r policies in Sri Lanka within the first two decades of the new millennium. Nearly 60% (68 policies) of the policies have been introduced within the aforementioned period. Further, of the 72 policies with positive impact direction, 49 (68%) have been introduced after the year 2000. The recent governments have taken a number of positive policy initiatives to curb Nr pollution caused by agriculture, industrial, waste, land use, energy and transport sectors in Sri Lanka.

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 Sri Lanka. These results highlight that current policy efforts so far have not yet been able to stabilise or reduce N_r emissions. In all cases, sector emissions are increasing for one or more compound. N_r emission levels will continue to increase unless further policy action is taken at international, national, and local levels. A range of sectors can be considered policy priorities in Sri Lanka due to the amount of N_r emissions produced and the rate of increases including agriculture, transport, energy, and waste.

Nitrogen oxides (NO_x) in Sri Lanka are the fastest rising N_r compound, particularly since the year 2000 increasing by +43% from 2000 and 2015. For ammonia (NH_3) and nitrous oxides (N_2O) emission levels in Sri Lanka have been increasing steadily, and at a somewhat similar pace since the 1970s. Agriculture has been by far the largest contributor of N_2O and NH_3 emissions in Sri Lanka over the last two decades. Agriculture contributed to 67% of ammonia (NH_3) emissions in the year 2018. Power industry, waste, transport and other sectors were somewhat more minor contributors (relative to agriculture) to ammonia (NH_3) and nitrous oxides (N_2O). However, emissions from these sectors are increasing rapidly, such as power industry increased ammonia emissions by +393% from the year 2000 to 2018. For nitrogen oxides (NO_x) the main contributor is from the transport sector, more specifically road transport, which contributed in a major way to NO_x emissions in 2018. The transportation sector has grown significantly in recent decades, causing emissions of nitrogen oxides (NO_x) to rise (+76% from 2000 to 2018). The second largest contributor to NO_x emissions in Sri Lanka is the energy sector. As per the data of 2018, energy sector contributed to 26% of nitrogen oxide (NO_x) emissions in Sri Lanka.

Recommendations: Action is needed in emerging sectors, considering relative changes in N_r emissions. Different sectors contribute to the emission of N_r compounds in various ways and are growing at different rates. The overlap in contributing sectors to different compounds indicates areas where integrated policies are necessary to avoid pollution swapping and promote coordinated actions.

In Sri Lanka, 56 policies were highly related to nitrogen, but only a few of these specifically referenced nitrogen or its compounds. 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 deal more directly/effectively with nitrogen management by referring explicitly to nitrogen pollution itself, and ideally to specific relevant N_r compounds. In order to address nitrogen pollution issues, amendments – ranging from minor to major ones – could be applied to these policies

For policies with high nitrogen management relevance amendments to specify pollution source type and the risk of nitrogen waste would be advantageous. Only a small number (9%) of directly nitrogen relevant policies (from a total of 115) determined if pollution sources were ‘point source’ locations or ‘non-point source’ or both. Such policies indicate potentially useful examples for N_r management.

Sector based policies would benefit from ensuring that they directly, or via other connected policies, consider the potential risks, or options to mitigate negative N_r impacts referring to one or more environmental sink. A large proportion (28%) of Sri Lanka’s nitrogen relevant sector-based policies have not referenced any sinks.

To deal with N_r pollution better, it is necessary to have policies that consider multiple sectors and sinks and policy instruments. Currently, nine policies meet this criterion to some degree. Although not all policies would need to be integrated in this manner, a policy gap is visible.

A large fraction of Sri Lanka’s population (40%) rely on agriculture for a living. This sector is also a core contributor to national N_r emissions. Fertilizers play a vital role but much of the inputs are wasted with the main source as ‘Direct N_2O Emissions from managed soils’. Sustainable alternatives are available. Such methods have the potential to save considerable revenue, maintain soil and human health.

Policies could more effectively minimize nitrogen waste in traditional farming systems if such policies have provisions to integrate science-based modern technologies with time-tested indigenous knowledge. Integrated policies promoting environmental stewardship could also be identified as a policy priority. Such policies will enable agro-ecological region and social-ecological system specific research and extension to improve nitrogen use efficiencies across different farming systems in the country. Such policies will have instruments directing and enabling local authorities to concider all the region/ farming system variables (i.e., climatic, edaphic, socio-cultural, traditional knowledge systems and shocks and trends etc.) in implementing and designing strategies to minimize nitrogen waste within their localities.

In the face of the current economic crisis, Sri Lankan agriculture sector is more likely to face drastic changes (e.g., bringing more land under farming to increase domestic production of food), Thus, it is very critical to amend existing policies or introduce new policies to meet the new challenges and ensure food security while minimizing pressure on the environment.

The development of National Action Plans are advised in the United Nations Environment Assembly (UNEA-5) new resolution on sustainable nitrogen management. Sri Lanka has the ability to strengthen regional/international commitments such as support of UNEA-5.2 and preparing for UNEA-6 to manage nitrogen sustainably.

Further in-depth research on these N_r relevant policies is 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 Sri Lanka's contributions to address N_r both nationally, regionally and beyond.

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Appendix

Table 21. Classifications used in the SANH policy analysis approach

Classification	Codes	Description
Sink:	Water; Air; Climate; Soil; Ecosystem; Multiple (if more than one sink was referred to); & Not Applicable (NA) (if no sink was referred to).	If the policy objective or content mentioned one or more sinks. Classifications were not based on assumed links or impacts. A sink refers to a reservoir that takes up a nitrogen or, where nitrogen loads can accumulate and can have an 'impact'.
Sector:	**Main sectors:** Agriculture; Energy; Food; Industry; Land Use Change; Transport; Urban Development & Tourism; Waste; Other; Multiple; Not Applicable (NA).	Policies were coded to a main sector. Where possible, they were also coded to a sub-sector, indicating the specificity of a policy. If the policy covered multiple sub-sectors, categorising as a main sector was sufficient.
Policy type. (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* covers pollution that comes from many land, air or water sources and can be carried overland, underground, or in the atmosphere, making them difficult to measure and control (Islam et al. 2018; Liu et al 2020). A policy would be classified as this if it states actions to target/control/measure non-point source pollution.
	Both	Policies refer targeting both point and non-point source pollution
	Unspecified	For policies that do not reference or recognise the different types of N pollution sources, and do not specify any intention/ measure/control pollution from either of those source types.
	NA	The default classification for Policies classified with a *negative* impact direction, and/or as having an *indirect relevance* received.
Impact direction	Positive	A policy was coded with 'positive' impact if it promoted a reduction in N pollution and/or improved nitrogen management whether directly or indirectly. This would likely include policies that were environmentally oriented such as; environmental standards, and water quality control policies.
	Mixed/ neutral	Policies coded 'mixed neutral' if it could do both, e.g., aiming to enhance food production but also considering environmental impacts,

		or if the policy is potentially neutral in its impacts
	Negative	A policy that could potentially cause excess nitrogen, such as those that promote synthetic fertiliser use or fossil fuels, would be coded as 'negative' e.g. promotion of fossil fuels
Impact scope:	Large	This classification was for distinguishing the scale of 'possible' impact a policy could have on N use. 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[7].
	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.

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

Table 23. Sri Lanka nitrogen-related policies that refer to high relevance, large scope, multiple type and mixed policy types and at least supported by an economic or regulatory instrument
Rubber Replanting Subsidy Act of 1953
Tea Subsidy Act (No. 12 of 1958)
Tea and Rubber Subsidy (Amendment) Act, No. 4 of 1970
National Environmental Act No. 47 of 1980
National Environmental (Amendment) Act, No. 56 of 1988
National Environmental (Ambient Air Quality) Regulations of 1994
Chemical Weapons Convention Act, No. 58 of 2007
National Environmental (Protection and Quality) Regulations (No. 1 of 2008)
Permissible Ambient Air Quality Standards in relation to class of Air Pollutants (Amendment 2008)
Action plan for haritha Lanka Programme (2009)
Fertilizer (Import, Manufacture and Formulation) Regulations, No. 1 of 2010
Marine Environmental Protection (Issuance of Permits for Dumping at Sea) of 2013
National Environmental (Air Emission, Fuel and Vehicle Importation Standards) Regulations No. 1 of 2003 Amendment July 2018
National Environmental (Air Emission, Fuel and Vehicle Importation Standards) Regulations No. 1 of 2003 Amendment August 2018
Vision 2025 (A Country Enriched)
National Environmental (Stationary Sources Emission Control) Regulations, No. 01 of 2019
National Environmental (Ambient Water Quality) Regulations, No. 01 of 2019

Table 24. Trend in N_r gas emission from agriculture sector in Sri Lanka from 1970-2015

Year	NO_x		NH_3	
	Emission/ ton	**Annual change %**	**Emission/ ton**	**Annual change %**
1970	1707.21	-	20968.21	-
1980	2155.25	5.86	28323.82	9.85
1990	2301.88	-5.29	30413.10	-7.70
2000	2317.00	-2.50	35350.16	-3.18
2010	2503.89	5.54	39306.59	3.55
2015	3139.66	11.81	50673.87	16.24

Source: Emission Database for Global Atmospheric Research (EDGAR), 2021

Table 25. Trend in N_r gas emission from energy sector in Sri Lanka from 1970-2015

Year	NO_x		NH_3		N_2O	
	Emission/ ton	**Annual change %**	**Emission/ ton**	**Annual change %**	**Emission/ ton**	**Annual change %**
1970	191.07	-	3.01	-	80.00	-
1980	1602.37	218.80	14.06	120.72	570.00	159.09
1990	69.41	-85.67	0.30	-85.78	10.00	-88.89
2000	45250.79	119.48	154.93	122.50	7220.00	122.15
2010	51601.56	-16.43	180.08	-14.24	8780.00	-13.33
2015	46449.78	-25.06	106.48	-36.92	28480.00	13.97

Source: Emission Database for Global Atmospheric Research (EDGAR), 2021

Table 26. Trend in N_r gas emission from industrial sector in Sri Lanka from 1970-2015

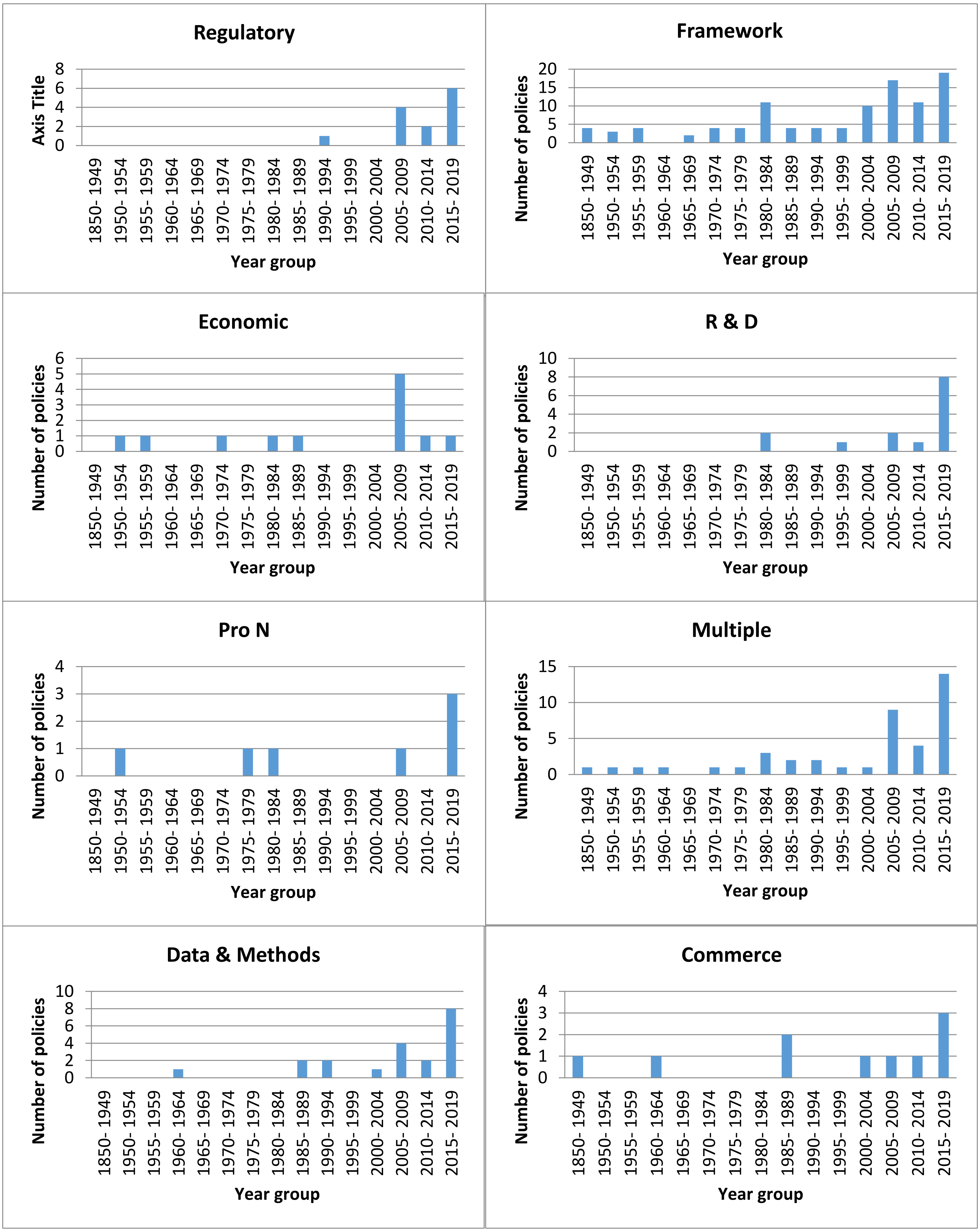
Year	NO_x		NH_3		N_2O	
	Emission/ ton	**Annual change %**	**Emission/ ton**	**Annual change %**	**Emission/ ton**	**Annual change %**

1970	9311.28	-	1771.63	-	21790.00	-
1980	8003.92	-8.90	1794.14	-7.64	22360.00	-7.64
1990	7338.02	4.47	2646.65	1.48	30860.00	12.26
2000	15397.36	16.13	6187.70	34.91	66740.00	24.12
2010	18822.07	8.06	7292.12	22.01	79930.00	12.01
2015	26682.62	30.96	8037.93	4.57	95950.00	8.30
Source: Emission Database for Global Atmospheric Research (EDGAR), 2021						

Table 27. Trend in N_r gas emission from transport sector in Sri Lanka from 1970

Year	NO_x		NH_3		N_2O	
	Emission/ ton	**Annual change %**	**Emission/ ton**	**Annual change %**	**Emission/ ton**	**Annual change %**
1970	15288.98	-	10.83	-	13890.00	-
1980	21332.16	-1.62	28.38	17.71	22830.00	1.33
1990	27387.6	3.68	22.42	7.48	23530.00	4.95
2000	53847.93	-1.73	50.97	-16.82	35010.00	-5.58
2010	72634.53	31.52	91.54	9.68	47770.00	15.90
2015	94561.73	10.92	99.86	0.15	64220.00	4.41
Source: Emission Database for Global Atmospheric Research (EDGAR), 2021						

Figure 27. Chronology of Sri Lanka nitrogen-related policies by policy type



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