Nepal Nitrogen Policy Report: Scientific Evidence, Current Initiatives and Policy Landscape

Kathmandu University (KU)
South Asian Nitrogen Hub (SANH)

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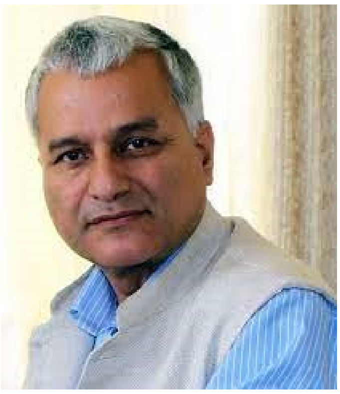
Foreword – Message from the Registrar of Kathmandu University



It is my great pleasure to see an important coverage of nitrogen relevant policies of Nepal in the form of a national report. To the best of my knowledge, such policies were scattered in various places in the electronic and printed forms. With the tremendous support of UKRI GCRF South Asian Nitrogen Hub (SANH), especially Work Package (WP) leaders of 1.1 and great effort of Nepalese team, the document made the reality in terms of understanding the N-policies, their impact in national, regional and global level and interpretation of the policies so as to make the best use of nitrogen with minimal environmental pollution. This report has nicely demonstrated the issues as well as challenges around nitrogen pollution and management, overview of nitrogen issues at the global and national scale, results from the SANH nitrogen policy data set and case studies. Detailed and scientific discussion of policies covering sectors such as agriculture, transport, tourism and the impacts of these policies will certainly be an asset to the people of Nepal, relevant stakeholders and eventually to the Government of Nepal. This report will also make the basis for developing future policies and will also provide inputs in the achievements/lapses/potential area of improvement in nitrogen sector.

I am grateful to my team who have worked hard to compile, analyze and discuss the policies. I sincerely believe that this document will be instrumental for the people directly/indirectly linked with nitrogen and will also get viewers and impacts in Nepal, South Asian region and finally across the world.

Prof Dr Subodh Sharma
Registrar, Kathmandu University
Kathmandu, June 2022

Foreword - Message from the Director of South Asian Nitrogen Hub

This report, prepared by Kathmandu University 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

Introduction

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, ecosystems and biodiversity. Addressing climate change by reducing greenhouse gas (GHG) emissions is a key priority in international politics. Excess reactive nitrogen (N_r) is a significant issue globally and for South Asia.

Managing nitrogen is essential for international climate change mitigation. A GHG such as nitrous oxide (N_2O) is 300 times more powerful than carbon dioxide (CO_2) produced by industry and through combustion. Nitrogen pollution may be managed directly or indirectly by legislation, financial or regulatory measures taken by governments. Furthermore, government and non-government measures can also support and encourage nitrogen management more efficiently, and hence, minimize the negative impacts.

The management of nitrogen is a major issue of international policy, and international policy actions can be more easily tracked. Information about nitrogen policies at national levels, however, is scarce. There is limited understanding of the number of present nitrogen-related policies, the issues addressed, and the types of instruments being used. Further, how existing policies might lead to increases in nitrogen pollution is also unclear. Evaluating nitrogen policies and related progress and barriers is a core aim of the UKRI GCRF South Asian Nitrogen Hub (SANH). SANH aims to aims to tackle the nitrogen challenge by bringing together experts from leading research organizations from across South Asia and the UK.

The South Asia Co-operative Environment Programme (SACEP) and SANH undertook an initial South Asian regional assessment of nitrogen emissions and policy context. The results were summarized in a report (SACEP-SANH 2022) and featured in a scientific journal (Yang et al. 2022). In addition, we created a new open access database that includes 966 nitrogen-relevant policies from South Asia. Drawing on that database, this SANH national report outlines the implications for Nepal of these findings.

This report provides a necessary step to understanding the current nitrogen policy landscape for Nepal within the broader South Asian context. It highlights the issues and challenges around nitrogen pollution and management at the global and national scale. The methods and results from the SANH nitrogen policy dataset have been presented alongside the drivers of emissions and policy trends at the country level. Finally, the report discusses emerging issues and provides case study overviews into some significant nitrogen control policies.

This report is the first of its kind to provide a national overview on the extent of nitrogen-related policies for Nepal. In total, 108 policies, including both directly relevant and indirect policies, were considered. Nepal's nitrogen-related policies contribute to 11% of the overall policies collected from South Asia.

Country level profile

Nepal is located on the southern slopes of the Central Himalaya having an area of 147,181 sq. km. The area consists of about 86% of mountains and hills, while the remaining area has low-lying Terai plains. Within a short span of 145 km to 241 km, the altitude changes rapidly from 67 m above mean sea level to 8849 m, giving rise to unique physiographic regions, climatic characteristics, biodiversity, ecosystem, agriculture, or settlements. The Nepalese economy relies heavily upon the agriculture sector which is a source of livelihoods for 66% of the country's active population and contributes about 29% to the total gross domestic product (GDP) (Kharal, Khanal, & Pandey, 2018). However, Nepal is considered as a food insecure country with very low (around 16%) arable land area. About 86% of the total area of Nepal is occupied by hilly and mountain regions where cultivation is difficult, mainly due to its topography.

Nitrogen-related policy analysis

A total of 108 nitrogen-related policies were collected and then classified based on certain characteristics to identify patterns in the types of policies in place for the country. Policies were classified by environmental sink; sector; sub-sector; policy type; pollution source type; impact direction; relevance; and impact scope.

Policy type, as a classification category, indicates the type of policy instruments that are being suggested or applied within a particular policy. A single policy may have multiple policy type characteristics for e.g., framework, data and methods and research and development (R&D). **For Nepal, there were 174 classifications from the 108 policies, 43 policies (40%) of which had more than one policy type identification**. Policies with multiple instruments are favourable since they indicate a more comprehensive approach.

Sector-wise the most common classification of policies was for multiple sectors at 43%. This is an advantageous policy characteristic indicating and understanding that multiple sectors have roles to play in N_r management. Some policy examples include the 'National Environment Policy, 2019 and 'Environment Protection Act 2019'.

For sinks, the most common classification was where 'no sink' had been included in the policy text (44%). In other words, over half of the policies collected were purely sector oriented. This could be regarded as an unfavourable policy characteristic as it indicates that such policies have not considered the potential risks or options to mitigate negative N_r environmental impacts. Purely sector-oriented policies included the 'National Transport Policy, 2001' and the 'National Agriculture Policy, 2004'.

By a cross comparison of classifications, the results indicated that most combinations of policy type and sink range from 0 to 5%. **The most common combination (24%) was for framework policies that were sector oriented only (i.e., included no sink).** Following this, framework policy types, with multiple sinks, were the most common combination (14%). Multiple sinks also had a higher percentage (relative to other combinations) for data and method (4%) and Research & Development (5%) policy types. Likewise, policies focused on 'ecosystem' sinks had a higher percentage (9%) with framework policy types.

Policies were further assessed based on their relevance to nitrogen management. **By removing those policies classified as having low relevance and/or low impact**

scope (omitting 43 policies, 39%), 65 policies were left for detailed assessment. These 66 'selected' policies 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 however be considered as irrelevant, as such policies still hold potential to have an impact and via amendments could be better adapted to mitigate N_r waste.

Most nitrogen-related policies (33%) were established in 2011-2019 followed by the policies established in 2001-2011 (31%). The classifications for 'multiple' and 'agriculture' sectors were the highest, relative to the other classifications, for all the years, but the highest number of policies were established in both the cases between 2011 and 2019. Likewise, polices that featured 'multiple' sinks had the highest number of policies established more recently (in 2011-2019).

Out of 108 policies, over half the policies (54%) were identified as having a potentially positive impact on N_r management. These policies include environmentally orientated policies such as those that aim to address pollution reduction and minimization, low carbon, and renewable energy. Those policies classified as mixed/neutral (41%), indicate dual goals for economic development and also considered the environmental implications to varying degrees. **Policies with a potentially negative impact direction, including those that risk promoting N_r waste, were low in number (5%).**

Policies that address multiple sinks and/or sectors (with integrated objectives), identify pollution sources, and contain multiple policy types are best placed to confront the multidimensional challenges of nitrogen management. The Intergovernmental Panel on Climate Change (IPCC), amongst others, advocate adopting a combination of policy instruments in order to secure better environmental outcomes than is possible from individual policy instruments (Gupta et al., 2007**). Only a few policies (4) in Nepal such as, 'National Environment Policy, 2019', and 'Environment Protection Act, 2019', described in the case study section, had integrated objectives i.e. addressed multiple sectors and sinks and included multiple policy instruments**. Policies that are highly relevant to nitrogen, that fall short on these criteria, can nevertheless be adapted to deal with nitrogen more directly and effectively in an integrated manner.

Drivers of reactive nitrogen emissions

Emissions from all three nitrogen compounds, ammonia, (NH_3), nitrogen oxides (NO_x), and nitrous oxide (N_2O), have been increasing over time. These results highlight that current policy efforts so far have not yet been able to stabilise or reduce N_r emissions. N_r emission levels will continue to increase unless further policy action is taken at international, national, and local levels. **Nitrogen oxides (NO_x) in Nepal are the fastest rising N_r compound, particularly since the year 2000. For ammonia (NH_3) and nitrous oxides (N_2O) the emission levels in Nepal have been increasing steadily, and at a somewhat similar pace since the 1970's.**

The emissions for NH_3, NO_x, and N_2O were, respectively, 150, 87 and 6166 Gg/year in 2015. The greatest change has occurred with nitrogen oxides (NO_x) with a 67% increase from 2000 and 2015. There was a 43% increase in nitrous oxide (N_2O). With the increasing trend of nitrogenous compounds, recent policies have been developing with multiple sectors and without addressing any sink. Sinks reflect the environmental aspect at risk (under threat) from N_r. Though the directly relevant policies in Nepal are comparatively lower in number, multiple sector-focused policies have been established.

Sectors such as agriculture, transport, industry, and energy have given rise to sharp increases in the levels of greenhouse gases and nitrogen pollution. In Nepal, the major sectors contributing to reactive nitrogen emissions are agriculture, buildings, transport, other industrial combustion, waste and power industry.

Agriculture is a common emission source for all three N_r compounds (NO_x, NH_3 and N_2O). For largely populated and developing countries, such as Nepal, more than half of the nation's population commonly occupy agriculturally viable areas. **The contribution to ammonia emissions by the agriculture sector is greatest (64%). Likewise, the agriculture sector also contributes to NO_x and N_2O at 15% and 76% respectively.** Urea nitrogen fertilizer inputs have increased steadily over the last decade. Subsistence agriculture is dominant in the hilly and mountain regions of the country, whereas commercial agriculture is practiced in the *terai* (lowland) where indiscriminate fertilizer use and repeated intensive cropping is having an adverse impact on soil health and the environment leading to the N pollution.

Road transportation accounts for one of the major sources of nitrogen emissions, and the transportation sector has grown significantly in recent decades, which is causing emissions of nitrogen oxides (NO_x) to rise. As per the data of 2015, 27% of nitrogen oxides are emitted from the transport sector. The increasing number of vehicles and petroleum products contributes to GHG emissions and air pollutants such as NO_x.

Similarly, the industrial sector is expected to expand significantly in the coming years. It is one of the major sectors which through its growth and development can massively drive the economy of Nepal. Even though the growth of the industrial sector is low in Nepal, it is already a significant source of air and water pollution. As per the data of 2015, **manufacturing industries and construction contribute 32% to nitrogen oxide (NO_x) emission**.

In addition, several greenhouse gases (GHGs), $PM_{2.5}$, and NO_x are released during the disposal and treatment of solid waste and wastewater. For instance, the emission from the crop residue burning contributed 24.5 Gg/year of $PM_{2.5}$ in 2016/17. In most parts of Nepal, waste is disposed in a haphazard manner with no processing in landfills, open dump, riverbanks and, in some towns, by land filling in low lying areas. Similarly, household and industrial wastewater is also a significant contributor to N pollution including GHGs.

To identify where action is needed in emerging sectors, relative changes in N_r emissions need to be considered. 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 to mitigate excess N_r waste.[1]

[1] Pollution swapping occurs when a mitigation option introduced to reduce one pollutant results in an increase in a different pollutant.

Needed actions

Over half of the identified policies were identified to have the potential for a positive impact on N_r management. Nonetheless diverse policies that address multiple sinks and/or sectors, pollution sources, and contain various policy instruments, are potentially more effective and better placed to confront the multidimensional challenges of nitrogen management. Given the lack of policies that meet these conditions, a policy gap is visible. According to the findings of this report some recommendations are provided, e.g.

- In Nepal, 28 out of 108 policies were highly and directly related to nitrogen, but only a few of these have specifically referenced nitrogen. As well as addressing nitrogen management systematically, such policies should also be accompanied by more direct actions, such as 'core' policies, that will facilitate and encourage efficient and effective nitrogen management. Regulatory and economic policies are core policies to reduce N pollution measurable levels. Nepal must set quantifiable and enforceable constraints on N production and consumption.
- Existing policies can also be adapted more directly/effectively to deal with nitrogen management. In some cases, policies such as the 'National Nutrition Policy and Strategy, 2004', or the 'Pesticides Rule, 1994', classified as being of medium to low relevance, do not directly relate to nitrogen management, but can still have implications. In order to address nitrogen pollution issues, amendments – ranging from minor to major ones – could be applied to these policies to refer explicitly to nitrogen pollution itself, and ideally to specific relevant N_r compounds.
- 61% of directly nitrogen relevant policies (17 from a total of 28) determined if pollution sources were 'point source' locations or 'non-point source' or both. Such policies indicate potentially useful examples for N_r management by recognising the differences in pollution sources and the specific requirements to measure and mitigate for them. For those policies that have high relevance for nitrogen management but not specify pollution source type nor the risk of nitrogen waste indicate a potential policy gap.
- Almost half of Nepal's policies relevant to N_r management refer to a sink (e.g. air, climate, soil, ecosystem, water), indicating a positive approach to reducing N_r emissions by considering environmental concerns and protecting the environment. Further investigation into the individual policies is required to investigate the policies collected and how outlined policy measures impact N_r management.
- A large proportion (43%) of Nepal's nitrogen relevant sector-based policies have not referenced sinks in their text. This is a policy gap, and such policies would benefit from ensuring that they are amended to directly, or via other connected policies, consider the potential risks, or options to mitigate negative N_r environmental impacts to either one or more environmental sink.
- To deal with N_r pollution better, it is necessary to have policies that consider multiple sources, impacts sectors and sinks. Likewise, it is further beneficial to have policies that include multiple policy instruments. Currently, four policies meet this criterion. Although not all policies would need to be integrated in this manner, given the small number of current policies,

increasing the number of policies with integrated features is recommended. Policy makers could also consider these points in the development of new N_r related policies.

- Agriculture is one of the main contributors to Nepal's GDP and fertilizers play a vital role. But much of the fertilizer input is wasted. Nearly half of N fertilizer input is not used by crops and is lost into the environment via emission of gases or by polluting water bodies (Martínez-Dalmau, 2021). As of 2020, chemical fertilizers are not produced in Nepal but are imported mostly from or through India and Bangladesh. At present, the use of chemical fertilizers is rising. Among them, urea and DAP are the most used source of nitrogen fertilizer. Alternatives are available, such as improvement of Farm Yield Manure (FYM), and promotion with subsidy in the field of organic manure use and production, modification in the agriculture practices like proper intercropping with legumes, and appropriate application method of recommended nitrogen fertilizer dose. Such methods have the potential to save considerable revenue, maintain soil and human health and hence, should be promoted. Along with such measures, effective enforcement of quality control standards at the point of sale, with sufficient human capacity is recommended at the government level.

- United Nations Environment Assembly (UNEA-5) has a new resolution on sustainable nitrogen management to develop national action plans for sustainable nitrogen management and Nepal has committed for the preparation of action plan to manage nitrogen. Nepal has the ability to strengthen regional/international commitments such as support of UNEA-5.2 and preparing for UNEA-6 to manage nitrogen sustainably.

- All the policies require further scrutiny to determine effectiveness on actual impacts on N_r management. Recognizing whether a policy may contribute to point source or non-point source (NPS) or both are also favourable characteristics for dealing with N_r management. It is recommended that further in-depth research on these N_r relevant policies is necessary, to assess, amongst other aspects, their policy impact.

- Science-based decision-making is very important 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 the most likely ways to mitigate their impact. Finally, the direct and indirect support of SANH will improve the scientific and technical base and help to create national nitrogen budgets which will help strengthen Nepal's contributions to address N_r both regionally and beyond.

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1. Introduction

1.1 Lead institution and SANH

Kathmandu University (KU) is an autonomous, not-for-profit, non-government institution dedicated to maintaining high standards of academic excellence. Pursuing the mission of providing quality education for leadership, KU is in the forefront of knowledge industry in the field of science and technology and education. Established in the year 2003, the Aquatic Ecology Centre (AEC) of Kathmandu University has set one of the objectives as to improve research and scientific networking. AEC aims to deliver analytical services to individuals, governmental and non-governmental organizations in the field of physiochemical and biological soil and water quality examination. One of the projects that falls under AEC is the "South Asian Nitrogen Hub (SANH)".

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

SANH includes institutions from 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.

The SANH research programmes focus on four key areas:

1. Building the nitrogen policy arena for South Asia;
2. Testing options for improving N management, from better 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 explain nitrogen flows between land, water and atmosphere across the region.

1.2 What is the purpose of this report?

This report provides a necessary step to understanding the current nitrogen policy landscape for Nepal 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 and emerging issues

v. Case study overview into some significant nitrogen control policies

vi. Recommendations

1.3 Why focus on nitrogen pollution?

Utilizing nitrogen, in its reactive form (N_r), has been essential for human development. Nitrogen has been altered in order to produce chemicals, 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 Figure 1).

Reductions in greenhouse gas (GHG) emissions are key to combating climate change, and a key area in international politics. The Paris agreement, in 2015, is a legally binding international commitment to limit global warming to well below 2°C, preferably to 1.5°C, 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 powerful 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 (European Commission, 2013). 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.

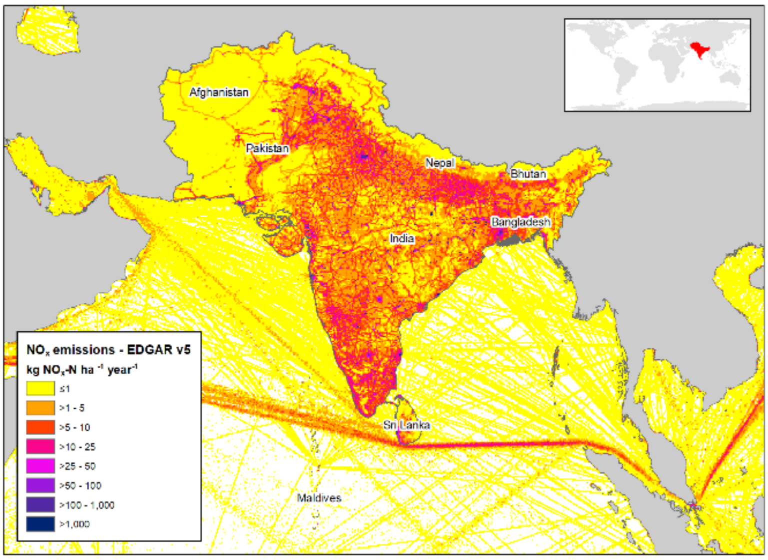


Figure 2: NO_x (nitrogen oxide) emissions across South Asia, 2015

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

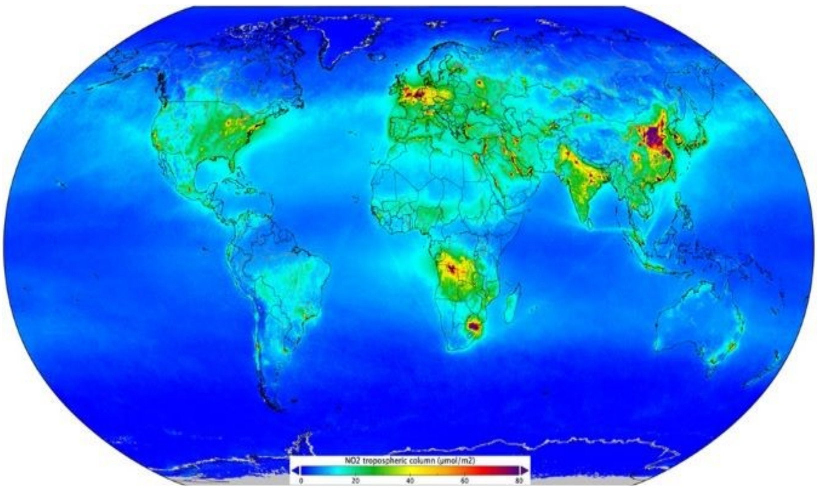


Figure 3: Global map of NO_2 (nitrogen dioxide) atmospheric pollution

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

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).

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.

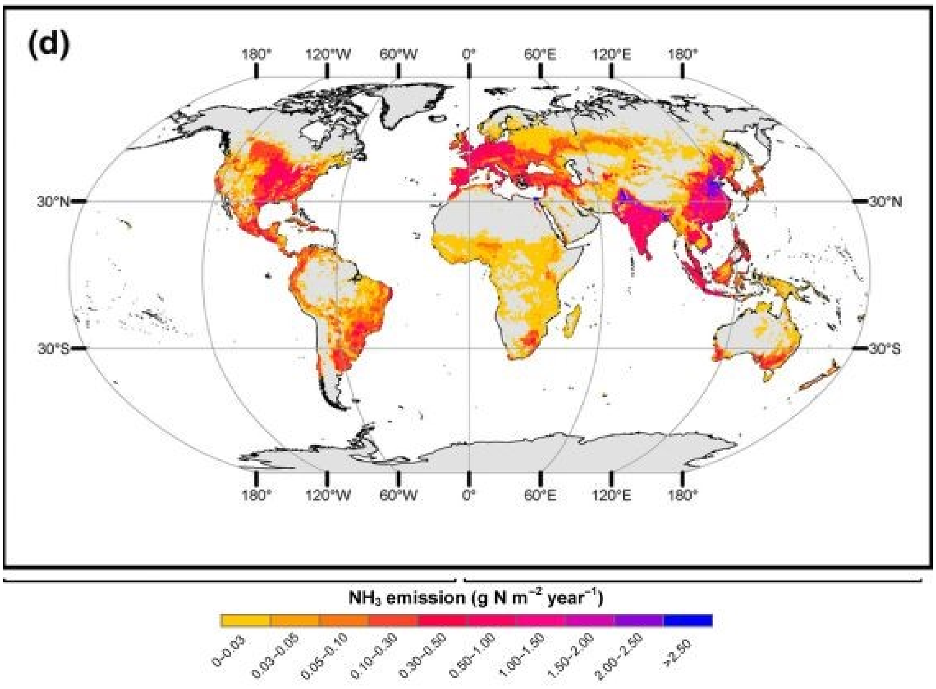


Figure 4: Global map of NH_3^- (ammonia) emissions

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.

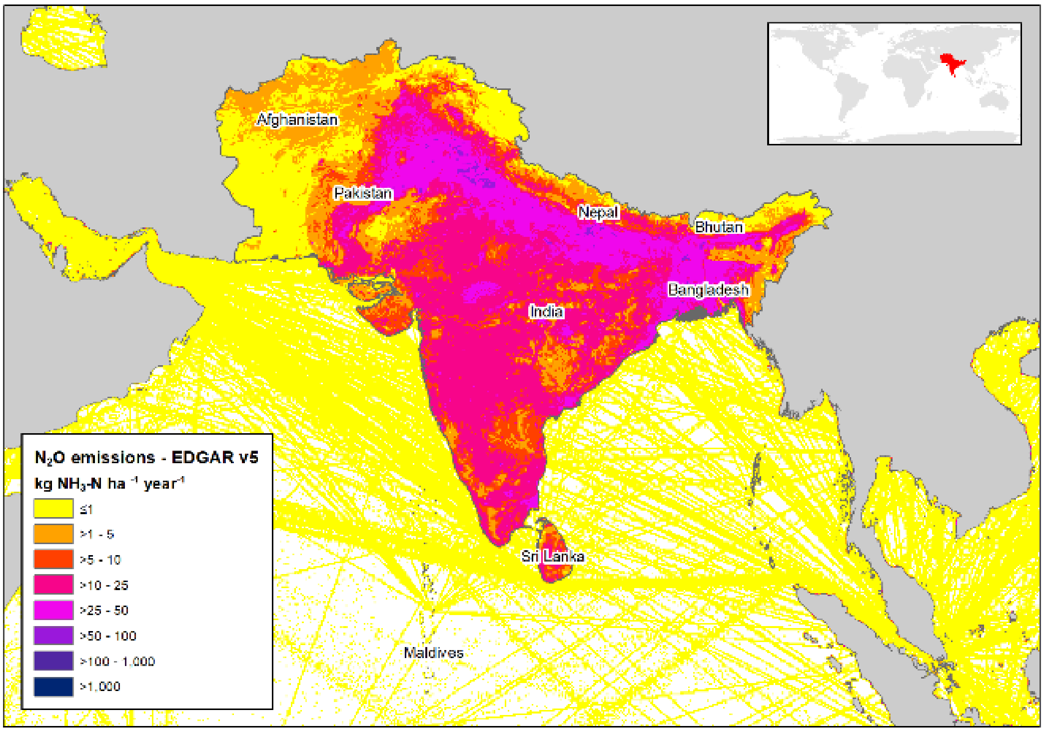


Figure 5: NH_3 (ammonia) emissions across South Asia, 2015

Source: SACEP-SANH (2022) EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa, et al (2019a). For more detail, see Appendix Figure 7.

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

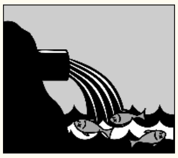
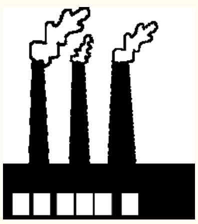
Provisioning, regulating, supporting and cultural ecosystem services [2] can be directly and indirectly affected by N_r. Impacts are further intensified via interactions with other human-caused environmental change, such as land use and climate change, along with other pollutants. For example, fertiliser runoff can cause freshwater eutrophication, leading to harmful algal blooms and dead zones, killing fish stocks, as visible in Figure 6.

Figure 6: Fish in an intensive monoculture pond in an eastern Bangladesh wetland. S*ource: 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).

[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)

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

Emission	Main Sources	Benefit	Environmental and health impacts
Nitrate (NO_3) 	Wastewater, agriculture and oxidation of NOx.	Widely used in fertilizer and explosives.	NO_3 forms particulate matter (PM) in air and affects health. In water it causes eutrophication.
Nitric oxide (NO) and nitrogen dioxide (NO_2) - collectively known as nitrogen oxides (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 airways, reduced lung functions, bronchitis, and cancers.
Ammonia (NH_3) 	Manure, urine, fertilizers, and biomass burning.	NH_3 is the foundation for amino acids, protein and enzymes. Ammonia is commonly used in fertiliser.	NH_3 is also an air pollutant and causes eutrophication and affects biodiversity. It forms particulate matter (PM) in air affecting health (See NO and NO_2 above). Modest odour contribution
Nitrous oxide (N_2O) 	Agriculture, industry, and combustion.	Used in rocket propellants and in medical procedures as laughing gas.	Health impact due to global warming as N_2O is a greenhouse gas (GHG), often enhanced by eutrophication health impact due to loss of stratospheric ozone depletion. In addition, the enhancement of vectors for infectious diseases (e.g., malaria) and frequency of infestations (e.g., algae blooms, insects etc.

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

SANH works across the eight south Asian counties to reinforce and support effective nitrogen management through a coordinated and integrated approach in the region. Collaborative efforts to tackle nitrogen are already underway. 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 Nation member states have endorsed a proposed roadmap for action addressing nitrogen challenges.

1.5 How can policy support sustainable nitrogen management?

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

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

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).

Photo: Nepalese farmer tilling a rice field by Sp Pradhan

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 Nr 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

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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' (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 from applications of fertiliser (European Commission, 2013).

Improvements to NUE require changes to agricultural practices. Scientists argue that sustainable agriculture practices, especially those closer to the natural systems as a way forward. Such practices can include "minimal tillage, intercropping, cover crops, catch crops, green manures (including legumes), animal manures, broad crop rotation, effective use of crop residues, and landscape planning" to reduce N_r waste and increase NUE (Jarvis et al., 2011; Sutton and Billen, 2010; European Commission, 2013). Yet any intervention can have drawbacks and the suitability will be site specific. Policy interventions can play a crucial role in guiding actions towards more efficient and effective nitrogen management.

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

Figure 7 gives some examples of other measures that can promote clean air practices to reduce PM pollution. These are 25 'most effective' measures listed by the Climate and Clean Air Coalition (CCA). 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 $PM_{2.5}$.

In science and policy, a multi-source, multi sector perspective will allow synergies and trade-offs to be better understood (UNEP 2019). In addition, a holistic and integrated and coherent approach is required to address the global

challenge of managing nitrogen effectively and efficiently. 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. 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 Grabosky,, 1998).

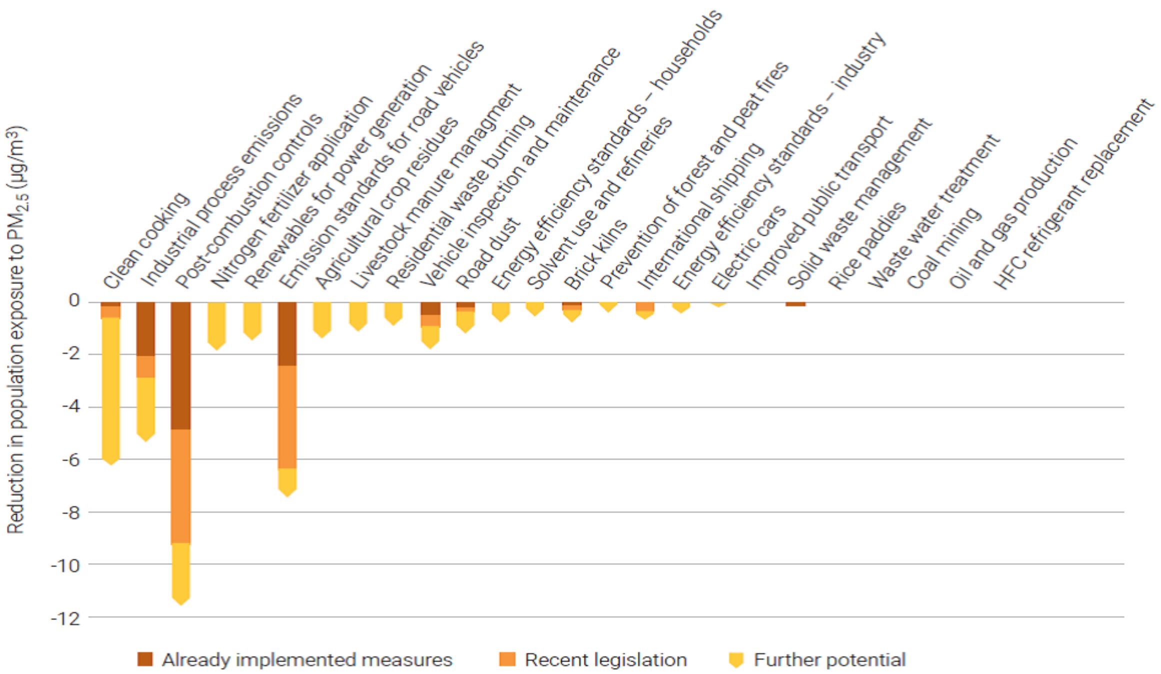


Figure 7: Impacts on population-weighted exposure to $PM_{2.5}$ in 2030 from implementation of 25 clean air measures, ranked by further potential

Source: Climate and Clean Air Coalition 2019; UNEP 2019 Interactions between sectors need to be considered alongside potential impacts to environmental sinks.

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 8). 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.

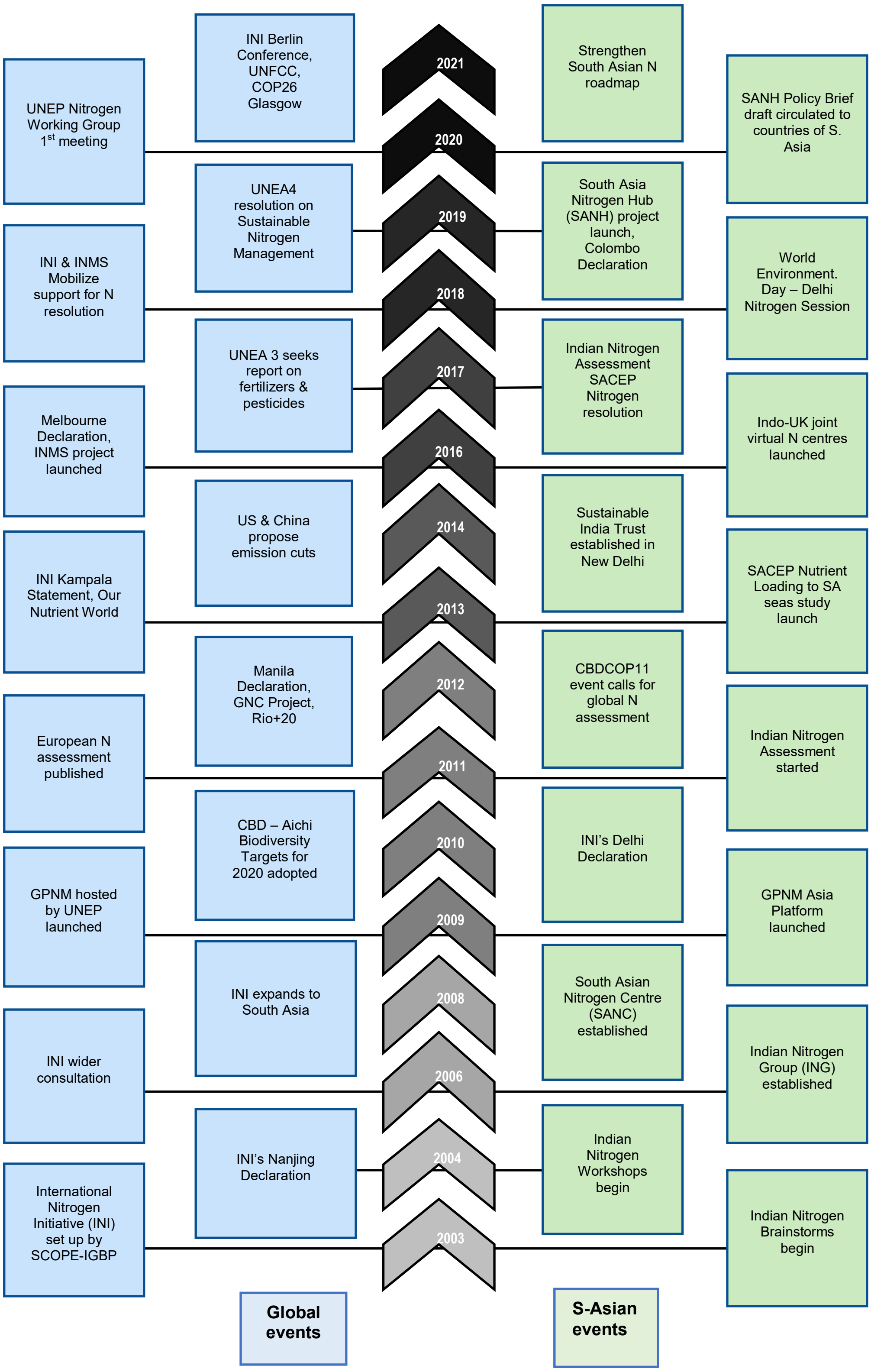
SANC also is part of the Global Partnership on Nutrient Management (GPNM) which forms a partnership of governments, scientists, policy makers, private sector, NGOs and international organizations to respond to the 'nutrient challenge'. The GPNM currently chaired by India, is under the UNEP Global Programme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

The UN Resolution on Sustainable Nitrogen Management (UNEP/EA.4/L.16) has further brought South Asia into global focus, leading to the Colombo declaration, on October 2019. With the declaration comes the ambition to 'halve nitrogen waste by 2030' whilst highlighting the multiple benefits across all the UN SDGs. 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 was adopted 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.

Figure 8: Timeline of global and South Asian developments toward global cooperation on sustainable nitrogen management

Source: Raghuram et al. 2021



1.7 What do we know about nitrogen policies?

Nitrogen management is a major international policy issue. International policy actions are easier to track. So far, very little is known about the nitrogen policy landscape at national levels (Kanter et al. 2020). There is a limited understanding of the number of current nitrogen-related policies, the issues they address, and the types of policy instruments being used. In addition, how existing policies may inadvertently lead to increases in nitrogen pollution is also poorly understood.

An initial international assessment attempted to address this knowledge gap by creating the world's first nitrogen pollution policy database. Kanter et al. (2020) identified 2,726 policies across 186 countries derived from the ECOLEX database, aiming to identify the gaps and opportunities in nitrogen policy, around the world. Overall, their analysis revealed that policy integration was limited and ill-equipped to deal with the cross-cutting nature of the global nitrogen challenge. Furthermore, the regional and country level implications of the nitrogen policy database they created are yet to be examined for South Asia. Making this step from global to regional analysis is a core aim of the SANH project. An initial regional assessment of nitrogen emissions and policy was undertaken by and SACEP and SANH (2022) for South Asia, and results are summarized in a joint report. These regional results were also featured in a scientific article (Yang et al. 2022). This SANH Nepal report outlines the country level implications of these earlier findings.

Policy fragmentation, and the lack of understanding on nitrogen-related policies and their trade-offs are barriers against tackling the nitrogen challenge. This is one of the challenges that SANH aims to examine.

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

2 Country level profile and priorities

2.1 Geopolitical and macroeconomics context of Nepal

Nepal is an independent country since the date of its evolution (Bhattarai, 2016) and is situated on the southern slope of the central Himalaya between two big and powerful countries India in the southern, eastern and western part and China in the Northern part. Nepal occupies a total area of the 1,47,516 sq. km with the latitudinal ranges 26°22' and 30°27'N and the longitudes 80°40' and 88°12' E. The summit of the Mount Everest is the highest point (8848.86 m) and Mukhiyapati (Dhanusha district) in the Terai is the lowest point (57 m) from the masl. Nepal is divided into five physiographical regions based on altitude i.e. Terai (14%), Siwalik (15%), Middle Mountains (29%), High Mountains (19%), and High Himal (23%) (Shrestha, & Cedamon, 2016). Nepal is a landlocked country for which the late King Prithvi Narayan Shah remarked Nepal as a "Yam between two Boulders".

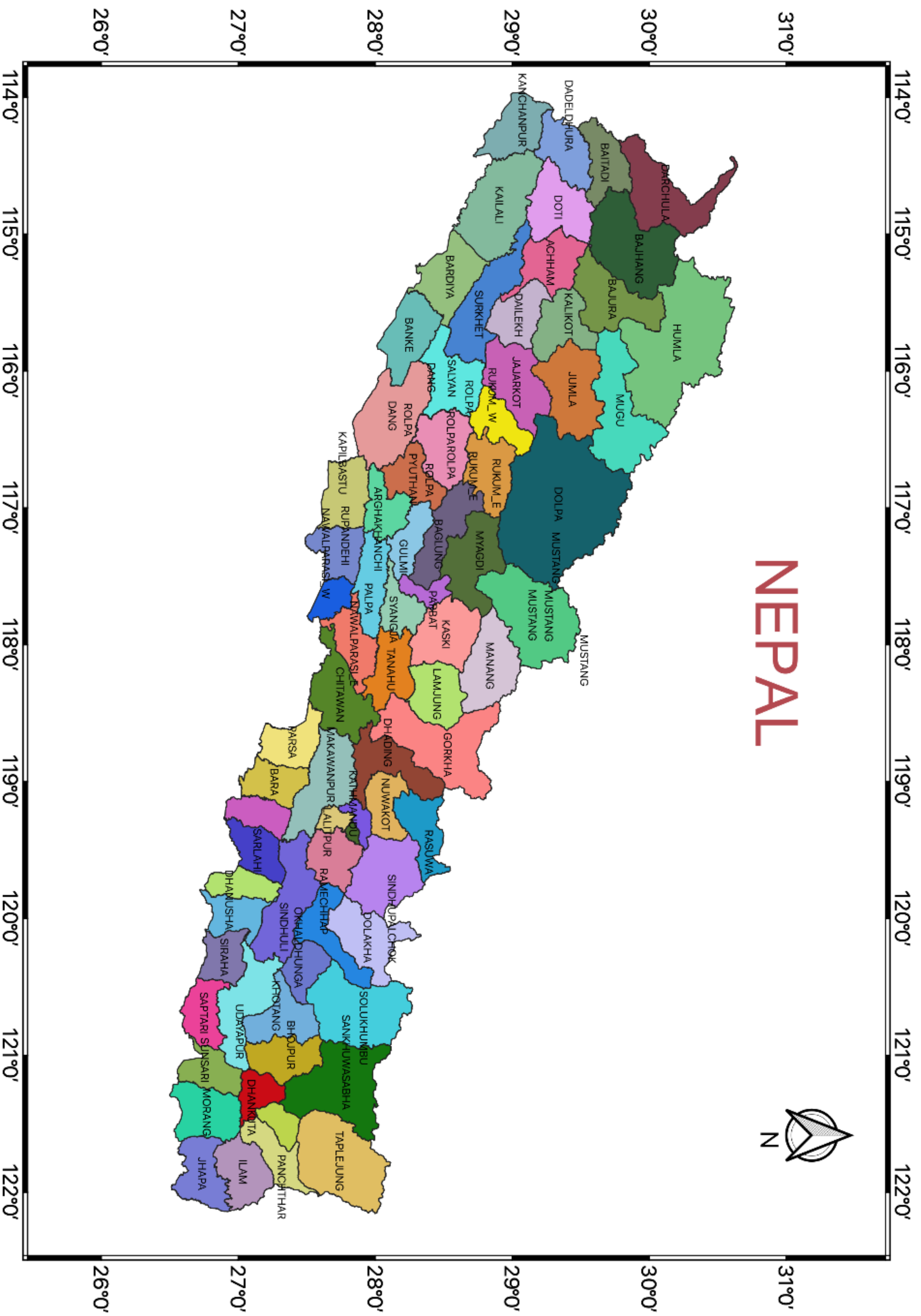
Administratively, the country is divided into seven provinces and 77 districts (Constitution of Nepal, 2072, Schedule 4) (Figure 9 and Table 2).

Table 2: Provinces of Nepal

Province no.	Total no. of districts	Name of districts
1	14	Taplejung, Panchthar, Illam, Sankhuwasabha, Tehrathum, Dhankuta, Bhojpur, Khotang, Solukhumbu, Okhaldhunga, Udayapur, Jhapa, Morang and Sunsari
2	8	Saptari, Siraha, Dhanusha, Mahottari, Sarlahi, Rautahat, Bara and Parsa
3	13	Dolakha, Ramechhap, Sindhuli, Kavrepalanchowk, Sindhupalchowk, Rasuwa, Nuwakot, Dhading, Chitwan, Makwanpur, Bhanktapur, Lalitpur and Kathmandu.
4	11	Gorkha, Lamjung, Tanahu, Kaski, Manang, Mustang, Parbat, Syanja, Myagdi, baglung and Nawalparasi (East of Bardaghat Susta).
5	12	Nawalparasi (West of Bardaghat Susta), Rupandehi, Kapilbastu, Palpa, Arghakhachi, Gulmi, Rukum (Eastern Part), Rolpa, Pyuthan, Dang, Banke and Bardiya.
6	10	Rukum (Western part), Salyan, Dolpa, Jumla, Mugu, Humla, Kalikot, Jajarkot, Dailekh and Surkhet
7	9	Bajura, Bajhang, Doti, Achham, Darchula, Baitadi, Dadeldhura, Kanchanpur and Kailali

Source: Constitution of Nepal, 2072, Schedule 4

Figure 9: Map of Nepal showing districts



2.2 Macro-economics of Nepal

Nepal has an estimated Gross Domestic Product (GDP) per capita of US$1,155 and is the national GDP was estimated at US$33.66 billion in 2020 (World Bank, 2022). GDP growth has fluctuated over the last couple of decades. The annual GDP growth rate peaked in 2017 at 9%, but dropped from 6.7% in 2019, to -2.1% in 2020 following the Covid-19 pandemic (World Bank, 2022).

The Covid-19 pandemic in Nepal has affected all sectors within the country including agriculture. The farmers were unable to sell their products in the markets, which negatively affected income and food security. As a result the GDP of Nepal has contracted (ADB, 2021). According to the economic survey conducted by Ministry of Finance (MoF) in the fiscal year 2019/20, the contribution of the agricultural sector to the total GDP is estimated to be 27.7% (Karn, 2021). Remittances have become the backbone of many developing countries like Nepal, and it contributed around 25.4% to the national GDP in the fiscal year 2018/19 which is also a major source of foreign income. The foreign remittance flow between mid-March 2020 to mid-August decreased because a large number of people remained unemployed abroad, and many of them returned home to Nepal due to worldwide lockdown (Karn, 2021).

2.3 Nepal's environment and its status

Nepal is one of the storehouses of biological diversity in the world as Nepal is standing at the transition zone comprising six floristic regions i.e., Central Asiatic - North, Sino- Japanese -East, Southeast Asia-Malaysian- South-east, Indian- South, Sudano Zambian- South west, Irano-Turranean- West (Government of Nepal/Ministry of Forests and Soil Conservation, GoN/MFSC 2009). Besides these, its unique geography and altitudinal variation (150-250 km) with north-south transect accompanied with high variability in physiographic and climatic conditions are other reasons for being rich in terms of biodiversity. Nepal has 12 global terrestrial ecoregions out of 867 (Wikramanayake et al., 2002) and six biomes (GoN/MFSC, 2009). There are 118 types of ecosystem (Dobremez, 1976) and 35 types of forest (Stainton, 1972; GoN & MFSC, 2014). In Nepal, forest ecosystem and vegetation vary with altitude, which ranges from near sea level to the highest point on earth.

Nepal occupies around 0.1% of global area and harbours 11,000 floral species (6,973 angiosperms, 26 gymnosperms, 534 pteridophytes, 1,150 bryophytes, 465 lichens, 1822 fungi, 1001 algae) which is 3.2% of the world's known flora. Similarly, it also harbours 1.1% of the world fauna which includes 5.2% of the world's known mammals, 9.5% birds, 5.1% gymnosperms, and 8.2% of bryophytes (GoN & MFSC, 2014). At present Nepal comprises of 44.74% forest area that is distributed across the four major geographic regions: the mountains, the mid-hills, the Siwalik and the Terai (Department of Forest Research and Survey, 2016) along with 23.4% of protected areas with 12 national parks, 1 wildlife reserve. 6 conservation areas, and 13 buffer zones (Department of National Parks and Wildlife Conservation, DNPWC, 2018). Nepal also has 37 Important Bird and Biodiversity Areas (DNPWC & BCN, 2018) and 10 wetlands have been listed as Ramsar sites. Similarly in Nepal, 19 plant species are tagged as protected species (GoN/MFSc, 2014). However, Nepal's biodiversity is threatened by multiple factors such as habitat loss, degradation and alteration of natural habitat.

2.3.1 Land use/cover profile and change

Land use and land cover change promote the transition to more sustainable production systems and practices in the crop, livestock, forestry and fisheries sector. Land use/cover is an important component in understanding the interactions of human activities with the environment (Choudhary & Pathak, 2016). Land use change can be categorized into two parts i.e., conversion which means change from one cover type to another and modification that means alteration of structure or function without a complete change from one type to another (Briassoulis, 2019). Table 3 illustrates overall land use profile of both times: 1960/70s and 2010s. Major portion of land (about 40 % of Nepal) is covered by forests followed by agriculture areas (Table 3).

Table 3: Land use/cover profile of Nepal

S.N.	Types of land use and units	1960/70s	2010s	Sources
1	Agricultural land (ha)	3,703,000 (1970)	4,388,000 (2010)	Paudel et. al. (2017)
2	Area under permanent crops (%)	0.7 (1962/63)	6.7 (2011/12)	CBS, 2019
3	Area under temporary crops (%)	92 (1961/62)	84.2(2011/12)	CBS, 2019
4	Area under woodland and forest (%)	0.8 (1961/62)	2.2 (2011/12)	CBS, 2019
5	Area under non-agricultural land (%)	3.5 (1961/62)	6.4 (2011/12)	CBS, 2019
6	Built-up area (%)	0.22 (1990)	0.34 (2010)	CBS, 2019
7	Forest (%)	38 (1978/79)	40.36 (2010/14)	DFRS, 2015
8	Shrub (%)	4.7 (1978/79)	4.4 (2010/14)	DFRS,2015
9	Area under community forest (million ha)	0.048 (1986)	1.88 (2018)	MoF, 2008; CBS, 2019
10	Area under leasehold forest (million ha)	0.007 (1998)	0.043 (2018)	MoF, 2008; CBS, 2019
11	Area under collaborative forest (million ha)	0.0067 (2008)	0.0734 (2018)	MoF, 2008; CBS, 2019

Table 3 shows that the area under temporary crops, shrub land has decreased while agricultural land, area under permanent crops, built up area, woodland and forest have increased. Conversion of cropland and forest land to urban uses is another important type of land use change because of its serious socio-economic and environmental implications (Briassoulis, 2019).

2.3.2 Water resources

In Nepal, there are four major Himalayan River systems namely, Koshi, Gandaki, Karnali and Mahakali. Few medium-sized perennial rivers originate from the middle mountain and Mahabharat range while a large number of small, seasonal rivers and streams arises from the Siwalik hill. Karnali has the largest catchment area (29.3%)

followed by Gandaki (21.7%), Koshi (19.0%) and Mahakali, which flows along the Nepal-India border (GoN & MFSC, 2014).

The UN SDG 6 clean water and sanitation aims to ensure access to safe water sources and sanitation for all. This goal has yet to be achieved, with only 18% of the population who can use safely managed drinking water services (SDG indicator 6.1.1., 2020) and around 49% of the population who can access safely managed sanitation services (SDG indicator 6.2.1a, 2020). In Nepal 47.8% of households use piped/tap water, while tubewell/hand pump is the main source of drinking water for 35% of the household, and 5.74%, 4.71% and 2.45% of the households use the spouts, uncovered wells and covered wells respectively (CBS, 2012).

2.3.3 Population change

Nepal is a multi-lingual, multi-religious, multi-ethnic and multi-cultural country occupied by 125 caste and ethnic groups, with a population of 29,136,808 with 1.8% population growth per annum in 2020 (United Nations, 2020). The density of the population varies from place to place. Kathmandu, the capital city has the highest population density (4,408 people per sq.km) while Mustang is a sparsely populated (3 people per sq.km) district of Nepal (CBS, 2012). Population changes from 1911 to 2011 are shown in the Appendix 2. Population growth rates have been fluctuating but overall decreased from 2.05% in 1971 to 0.1% in 2011 and then began to rise again after 2013. Since 1971, the proportion of the population living in urban areas has been increasing, from about 4%, to 6.4% in 1981, 9.2% in 1991, 14.2% in 2001, and 17% in 2011. Population density increased from 79 in 1971 to 181 pop./km^2 in 2011 (Regmi, 2014).

2.3.4 Agriculture

Nepal's economy is dependent on the use of natural resources, including agricultural lands, wetlands, forestlands and protected areas. The FAO estimates that 66% of the Nepalese population are directly engaged in farming (FAO, 2022) often for sustenance needs. Agriculture, forestry and fishing contributes to 23.1% of Nepal's GDP in 2021. Since the 1970's the contribution of this sector to GDP has been steadily declining, it peaked in 1975 at 69% dipping to 21.6% in 2019 (World Bank, 2022). Labour in agriculture has also changed, in 1991 agriculture in Nepal accounted for 82% of employment which was reduced to 64% in 2019 (Paudel & Wagle, 2019) (ILO, 2021). Table 4 illustrates the percentage of employment change across core sectors including the agricultural sector, between the years 1995 to 2010. The changes across the years indicate the employment shifts between sectors in both rural and urban areas.

Table 4: Composition of employment in the rural and urban areas in the year 1995 and 2010

Sectors	Employment change in Urban Area (%)			Employment change in Rural Area (%)		
	1995	2010	Change	1995	2010	Change
Agriculture	21.6	4.9	-16.7	63.4	33.9	-29.5
Mining, Manufacturing	13.4	25.5	+12.1	10.5	15	+4.5
Construction	6.4	9.7	+3.3	8.6	20.4	+11.8
Professional	4.8	14.6	+9.8	1.5	3.5	+2.0
Services	53.8	45.3	-8.5	16.1	27.2	+11.1

Source: Tiwari et al., 2016

Agriculture has been a vital sector of Nepal's economy for achieving the gains related to food security, employment generation and poverty reduction. In Nepal's agriculture sector around 550 crop species are identified as having food value, and half of them are under cultivation (MFSC, 2002). Major staple food crops produced in Nepal include ice, maize, millet, wheat, barley and buckwheat (FAO, 2022). Important cash crops include oilseeds, potato, tobacco, sugarcane, jute and cotton. Pulse crops include lentil, gram, pigeon pea, blackgram, horsegram and soybean. For farming households, livestock is also important for cash incomes largely through the selling of 'milk, yoghurt, cheese, ghee, Chhurpi, meat, egg and live animals and poultry' (FAO, 2022).

In Nepal, only 27% of agricultural land has access to irrigation and the rest of the countries arable land is rain-fed (Bocchiola, 2017). Due to the insufficient access to technologies, markets, inputs and services, the growth of agricultural production has shrunken in Nepal (Joshi, Conroy, & Witcombe, 2012). In Nepal, subsistence agriculture is dominant in the hilly and mountain regions of the country, whereas commercial agriculture is practiced in the terai (lowland) where indiscriminate fertilizer uses and repeated intensive cropping is having an adverse impact on soil health and the environment leading to the N pollution.

Chemjong & Yadav (220) argue that food insecurity in Nepal is associated with **the countries** "susceptibility to natural disasters, such as drought, governance, earthquake, floods, and landslides, vulnerability to fluctuations in global prices, civil turmoil, disease and poor infrastructures" (p.1). They report**ed** that in 2016 Nepal 4.6 million people are food-insecure, with 20% of household mildly food-insecure, 22% moderately food-insecure and 10% severely food-insecure.

Climate change has also impacted the agricultural sector. A study conducted by Bhatta et al., (2014) found that crop yield under historical climate (1967-2008) for rice, maize and wheat in the Koshi basin are facing significant impacts from growing temperature and precipitation. Rice, maize and wheat cultivated below 1100, 1350 and 170 msl respectively suffer from the stress of high temperature (Bhatta, Maskey, & MS, 2014). However, they also observed positive impacts of warming at some high elevation areas in the production of maize and wheat. Thus, adaptation strategies need to be prepared considering growing seasons, altitudes and the crops because it could be beneficial or harmful depending upon the crops and altitudes (Bocchiola, 2017). The Covid-19 pandemic and the Ukraine-Russia conflict puts further pressure on national food security in Nepal, with rises in food and fertilizer prices.

2.3.4.1 Fertilisers

Fertilisers play a vital role in agriculture and for ensuring food security. In the 1950s Chemical (synthetic) fertilizers were introduced to Nepal and since consumption has been growing. Takeshima (2019) reported that in the Terai, synthetic fertilizer consumption grew from 48 kg and 63 kg/ha in 1995 and 2003 to 117 kg/ha in 2010, while in the Hills it remained mostly stagnant and in the Mountains it even declined. DAP[3] (120,893 tonnes) and Urea (216,794 tonnes in 2019) are mostly used with little use of other complex fertilisers (FAOSTAT, 2022). See Appendix 4 for the agricultural use of the main synthetic fertilisers from 2003 to 2019.

[3] Diammonium phosphate (DAP)

It is reported that Nepal's total demand for synthetic fertilizer stands at 600,000 metric tons (MT) (as of February 2022) (CESIF, 2022). It is estimated that 25% of the country's fertiliser is domestically produced with 75% imported from neighbouring countries. Furthermore, 1/3 of this is reportedly imported through official channels and the rest via informal means (CESIF, 2022).

Fertiliser subsidies have been increasing in Nepal over the years. As a result fertilizer has become one of the largest spending items in the agricultural sector (Kyle et al. 2018). In 2016/2017 20% of the agricultural budget was spent towards fertiliser subsidies (Kyle et al. 2018). In the Kathmandu Post (2021) it was reported that DAP could be purchased in Nepal for round Rs90 per kg and it is sold at the subsidised rate of Rs44 per kg to farmers.

As of 2020, chemical fertilizers were not produced in Nepal but are imported mostly from or through India and Bangladesh. In March 2022, Nepal and India, signed a government-to-government (G2G) deal to procure synthetic fertilizers for the next five years. This arrangement intends to boost fertiliser supplies to the country. Nepal's fertiliser supplies have fluctuated and whilst they have reportedly improved over time, there are still significant constraints (Kyle et al. 2017). Constraints include the limited ability for farmers to purchase fertilisers in sufficient quantities, benefits going mostly to larger farms rather than smaller farmers, and poor coordination with crop–extension services limiting efficient fertilizer use (Kyle at al. 2017).

Global Nitrogen use is largely inefficient. Over half of N fertilizer inputs are not used by crops and is lost into the environment via emission of gases or by polluting water bodies (Zhang et al. 2021). In lowland Rice, Ladha et al. (2005), estimated that the nitrogen use efficiency (NUE) (defined as the fraction of applied N taken up by plants) rarely exceeds 30%.

Despite increasing trends in the use of Urea and DAP, alternatives to chemical fertilisers are also available and used. Nepalese farmers, also rely on livestock manure for nutrients, especially in the Hills and the Mountains (Takeshima 2019). The amount of manure applied to soils has also been increasing steadily in Nepal between 1961 (~33,666,852 kg) to 2019 (~105,863,467 kg), see Appendix 5.

Overall measures for improving nitrogen use in soils, and reducing waste, are available such as improvement of Farm Yield Manure (FYM) and promoting subsidy in the field of organic manure use and production, modification in the agriculture practices like proper intercropping with legumes, and appropriate application method of recommended nitrogen fertilizer dose. Such methods have the potential to save considerable revenue, maintain soil and human health and hence, should be promoted. Along with this, effective enforcement of quality control standards at the point of sale with enough human capacity should be provided from the government level.

2.4 Environmental and health impacts of nitrogen pollution in Nepal

The literature on impacts of nitrogen on the environment and people's health in Nepal is limited. However, it is clear from the available data that N_r emissions in Nepal are increasing rapidly and many environmental issues are either driven or compounded as N_r increases (Table 5).

2.4.1 Nitrogen emissions change and status in Nepal

Nitrogen pollution is formed when the deposition of the nitrogenous compounds like ammonia and nitrous oxide is too high. One plausible cause for it is the use of synthetic fertilizers. Population growth, rapid expansion of sprawling urban municipalities, increasing amounts of industrial and commercial activity, and rising consumption of packaged goods has resulted in the use of synthetic fertilizers which in turn has presented severe air and water quality issues, poor sanitation, and the spread of diseases (Pokharel & Vivaraghavan, 2005).

Table 5 shows that in Nepal, all three nitrogen compounds, ammonia, (NH_3), nitrogen oxides (NO_x), and nitrous oxide (N_2O), have significantly increased between the year 2000 and 2015. The greatest change has occurred with nitrogen oxides (NO_x) with a 67% increase from 2000 to 2015. Similarly, there was a 43% increase in nitrous oxide (N_2O) and 39% increase in ammonia emissions (NH_3) in Nepal, numbers that align with the average change for South Asia (36%)[4]. In overall quantities, Ammonia was the highest in 2015 at 149 Gg.

Table 5: National changes in emissions of key reactive nitrogen compounds, 2000-2015 for Nepal

Nepal	2000	2015	% Change
Ammonia – NH_3 emission (Gg/year)	107	149	39
Nitrogen oxides – NO_x emission (Gg/year)	52	87	67
Nitrous oxide – N_2O emission (Gg/year)	14.49	20.19	43

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

Nitrogen pollution can impact the environment in multiple ways and its effect can be detrimental to the air and water quality, climate, soil, and ecosystems, if not controlled.

2.4.2 Air pollution

Air pollution has been a serious problem in this 21st century for both the developed and developing world. The chances of non-communicable diseases such as heart disease, lung disease and cancers, respiratory diseases and allergy increase significantly due to the exposure to polluted air as it is considered a silent killer (Saud & Paudel, 2018) and air pollution is also responsible for 7 million deaths per year globally (WHO, 2016). Air pollution has adverse impacts on human health. Studies have shown that a global loss of $225 billion per year has been incurred due to pollution, of which South Asia has been most severely affected region suffering a loss of more than $66 billion alone i.e., approximately 1% of the Gross Domestic Product (World Bank, 2017). The Urban Health Initiative (UHI) initiated by WHO, has identified four primary sources of air pollution namely solid waste, transport, industry/brick kilns, and household energy sectors (Jaffee, 2020). The data shows that about 13% of GHG emission is contributed by nitrous oxide in Nepal as shown in Table 6. Nitrous oxide has 300 times more warming potential than the CO_2 and causes severe health issues.

[4](EDGAR), release EDGAR v6.0_GHG (1970 - 2018) of May 2021.)

Table 6: Total greenhouse gases (GHG), and nitrous oxide (N_2O) emission in Nepal

Year	Total GHG ($tCO_2eqGHG/cap/year$)	N_2O ($tCO_2eqN_2O/cap/year$)
2010	1.42	0.19
2011	1.45	0.19
2012	1.49	0.20
2013	1.48	0.21
2014	1.51	0.21
2015	1.50	0.21
2016	1.59	0.21
2017	1.69	0.22
2018	1.73	0.21

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

In Nepal, air pollution is a burning problem. The 'Constitution of Nepal 2015' states that clean and healthy environment should be guaranteed to the people as their primary right. Unfortunately, air pollution has had a massive negative impact in the health of Nepalese people. Every year, 35,000 people in Nepal die from illnesses related to air contaminants (Jaffee, 2020). Nepal is one of the top 10 countries with the highest levels of outdoor $PM_{2.5}$ according to the State of Global Air report 2020 (Health Effect Institute, 2020). According to the IQAir data for Nepal, $PM_{2.5}$ concentrations in the air are currently (as of 2022) 9.2 times above the WHO annual air quality guideline values. The Global Burden of Disease Report 2020 stated that 17,900 deaths in Nepal in 2019 were caused by $PM_{2.5}$ pollutions, made up by the substantial fraction of the reactive nitrogen (N_r) in the atmosphere (IHME, 2020). Deaths attributed to air pollution from the year 1990 to 2015 are shown in Figure 10. An estimated 215.6 in every 100,000 people of Nepal have died due to air pollution as of 2016 (State of Global Air 2018).

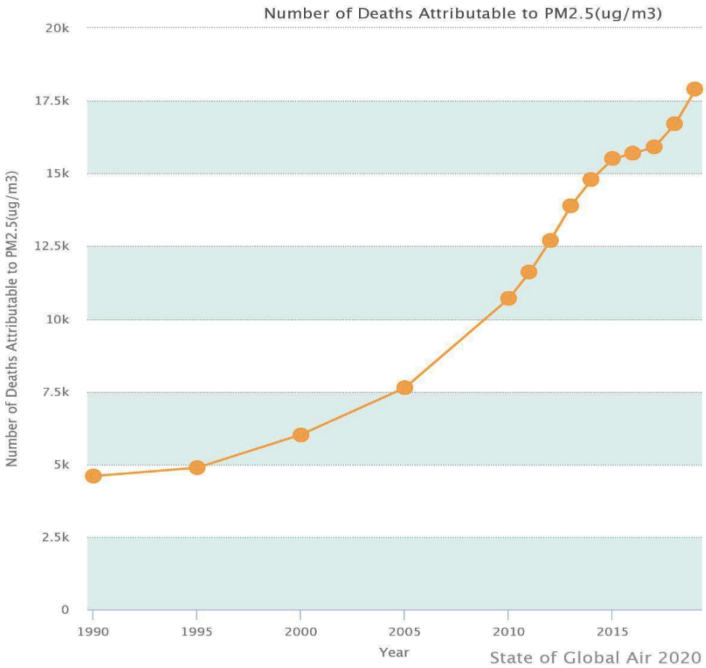


Figure 10: Deaths attributed to air pollution in Nepal
Source: Health Effect Institute, 2020

The Government of Nepal has taken different initiatives in the form of acts, rules and action plans to control air pollution. For instances, the 'National Plan for Electricity Mobility (NPEM)' includes several objectives: increasing the share of electric vehicles to 20% by the end of 2020, cutting fossil fuel use in the transport sector 50% by 2050 and developing a hydroelectric powered rail network by 2040 (Jaffee, 2020).

The rapid expansion of urban region and the growing number of vehicles and industrial sectors have led to the increment in the key gaseous air pollutants like SO_2, NO_x, NO_2, NH_3, and O_3. The urban sites were found to have higher weekly averages of NO_2 and SO_2 than sub-urban sites in 2013. The government has approved the "Kathmandu Valley Air Quality Management Action Plan" which tries to address the issues comprehensively. Likewise, there are 'Standard for Emission from Industrial Boilers, Standard for Emission from Cement and Crusher Industries', 'Standard for Emission from Diesel Generators', and 'Standard for Emission from Brick Kilns'.

The Department of Transport Management (DoTM), under the Ministry of Physical Infrastructure and Transport, has banned vehicles that are more than 20 years old. The decision was made in March 2015, but these rules are not adequately implemented. The 'National Ambient Air Quality Standards, 2004' has set the concentration of 80 $\mu g/m^3$ in averaging time 24 hours and 40 $\mu g/m^3$ in annual averaging time. The National Ambient Air Quality Standard is shown in Appendix 3.

2.4.3 Water pollution

Nepal's most pressing environmental quality issue is water pollution. Most of the water bodies in Nepal are now heavily polluted by sewage, industrial effluents, chemicals, and solid wastes and are unsafe for human use. Pit latrines and seepage tanks polluting the groundwater are also the source of nitrogenous compounds like ammonium nitrate. As groundwater is a source of drinking water this is an important health risk (Hammoud et al., 2018). Seasonal variations in the concentration of nitrogen compounds in groundwater were observed in the Kathmandu valley and higher fluctuation was observed in the gravel-bearing areas than in the clay-bearing areas (Shakya et. al., 2019).

According to the Department of Water Supply and Sewerage[5], despite 80% of the population having access to drinking water in Nepal, the water is still not safe to drink. In the rural areas mostly in the hilly regions, people are dependent on spring sources and small brooks running from the mountains and spend hours traveling to get water (Gurung et al., 2019). Climate change and other environmental and anthropogenic factors are affecting the water quality and quantity of the spring sources. In part, this is due to natural and anthropogenic contamination deteriorating the surface and ground waters. Industry and domestic waste pollute the surface water, as well as untreated sewage from densely populated cities add to the pollution.

Wastewater generated within industries contains many oxygen-depleting substances, synthetic organic compounds, inorganic chemicals, and minerals, which contribute to significant degradation of water quality and is mixed with public sewer systems. Further harmful solid waste is collected and disposed in open pits (Shukla,

[5] https://thewaterproject.org/water-crisis/water-in-crisis-nepal

Timilsina & Jha, n.d). Aside from wastewater and sewage from domestic and industrial sources, the rivers and other water sources are also subjected to storm water runoff from the streets and roads in urban areas, waste from the residential area as well as runoff from agricultural lands containing pesticides and fertilizers (Shukla, Timilsina & Jha, n.d.).

Industries, agricultural lands, and urban areas dispose the harmful pollutants, including nitrates. The concentration of nitrate in groundwater varies due to fertilizer applications in the field, animal farming, percolation from septic tanks, and wastewater discharges in the open field (Bhandari et al., 2021). In one of the studies conducted in Kathmandu valley in ninety sampling sites, including shallow tube wells, dug wells and stone spouts (locally called *Dhunge Dharas*), mean annual nitrate-N concentrations in shallow groundwater of Kathmandu ranged from 0 to 26.4 mg/L indicating its vulnerability to contamination (Pathak, Hiratsuka & Yamishiki, 2011). The results confirmed 16% of the sampled wells exceeded USEPA[6] guidelines of nitrate-N (Pathak, Hiratsuka & Yamishiki, 2011).

The Government of Nepal has issued a notice for the implementation of 'National drinking water quality standards, 2062' under the provision of 'Water Resources Act, 2049', Clause 18 and sub-class clause 1 where the nitrates and ammonia concentration limits are 50 mg/l and 1.5 mg/l respectively. The physical, chemical and microbial parameters of drinking water with the concentration limit are shown in Table 7.

Table 7: National drinking water quality standards

S.N.	Category	Parameters	Units	Concentration Limits
1	Physical	Turbidity	NTU	5 (10)
2		pH		6.5-8.5 *
3		Colour	TCU	5 (15)
4		Taste and odour		Non-objectionable
5		TDS	mg/L	1000
6		Electrical conductivity (EC)	ms/cm	1500
7	Chemical	Iron	mg/L	0.3 (3)
8		Manganese	mg/L mg/L	0.2
9		Arsenic	mg/L	0.05
10		Cadmium	mg/L	0.003
11		Chromium	mg/L	0.05
12		Cyanide	mg/L	0.07
13		Fluoride	mg/L	0.5-1.5 *
14		Lead	mg/L	0.01
15		**Ammonia**	**mg/L**	**1.5**
16		Chloride	mg/L	250
17		Sulphate	mg/L	250
18		**Nitrate**	**mg/L**	**50**
19		Copper	mg/L	1
20		Total Hardness	mg/L as $CaCO_3$	500
21		Calcium	mg/L	200
22		Zinc	mg/L	3
23		Mercury	mg/L	0.001

[6] United States Environmental Protection Agency (USEPA)

24		Aluminium	mg/L	0.2
25		Residual Chlorine	mg/L	0.1-0.2 *
26	Microbiological	E. Coli	MPN/100 ml	0
27		Total Coliform	MPN/100 ml	0 in 95% samples

Source: (GoN, 2005) National drinking water quality standards and directives, 2005

Water is one of the basic human necessities, but a large portion of the Nepalese population has been devoid of access to safe and adequate drinking water supply (see section 2.3.2 Water resources). Pollution has had effects on different physical, chemical, and biological water parameters. Water pollution across the globe and in Nepal have had negative effects on human health and have caused severe waterborne diseases (Bhattarai & Dahal, 2020).

2.4.4 Solid waste burning

The open burning of the municipal waste and the agricultural residue in the fields also contributes to problems from reactive nitrogen (N_r) emissions. Burning of garbage or simply waste incineration is usually an environmentally poor waste management option where potential resources are lost. It can also cause air, land and water pollution. The emission factor for the burning of biomass in the residential sector was 0.89 for NO_x in 2008 (NEEMI-Part I). IQAir[7], that conducts global air quality monitoring, showed that the Kathmandu was the most polluted city in the world on January 4, 2021. The level of $PM_{2.5}$ was observed to be 145 $\mu g/m^3$ on Friday at 10:45pm. Available data has indicated that the air quality in the capital city has been unsafe for several years now (Mandal, 2021).

Many municipalities are now experiencing extreme environmental degradation and public health risk due to haphazard disposal practices and unsanitary waste management (Nagpure et al., 2015). Burning of solid waste is practiced more in rural areas, but the problem is more severe in the urban areas as there is a higher volume of waste generated. Open burning is more frequent in the winter season hence pollution peaks during this season and the smoke coming from open burning is more toxic as the waste contains huge amount of plastic and other materials (Budhathoki, January 2021). According to Das et al. (2018) 7,400 tons of waste is burned every year or 20 tons of solid waste every day in Kathmandu valley i.e., 3% of the total solid waste and while burning 1 kg of waste, 100 grams of $PM_{2.5}$ are emitted.

Figure 11 shows air pollutants like $PM_{2.5}$ of 55 tons; PM_{10} of 60 tons, nitrogen oxides (NO_x) of 19.2 tons, and ammonia (NH_3) 5.7 tons per year are emitted to the environment from open burning of waste in the Kathmandu valley. Pollutants generated from open burning have triggered various health impacts such as acute and chronic respiratory disease, heart diseases, and allergic hypersensitivity (Das et al., 2018).

[7] A Swiss air quality technology company that provides real-time worldwide air quality data.

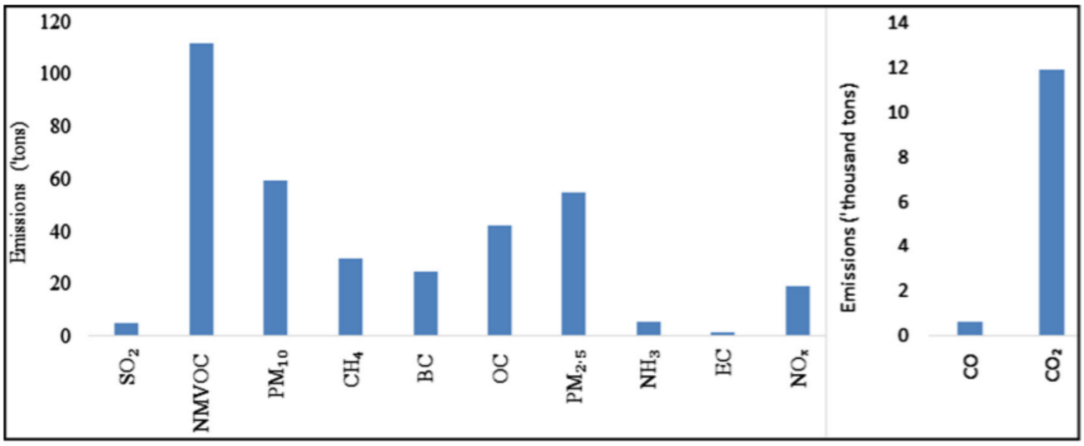


Figure 11: Emission from municipal solid waste of Kathmandu valley
Source: Das et al. 2018

2.4.5 Agriculture residue burning

Agriculture residue burning is a practice of regularly or periodically burning post-harvest biomass and excess vegetation after cereal harvests in the cultivated fields for preparing the field to sow for the next crop. Harmful pollutants like $PM_{2.5}$, nitrogen oxides (NO_x), and ammonia (NH_3) are emitted from open burning of crop residue and can trigger severe health impacts like respiratory disease, cardiovascular disease, allergies and premature deaths (Zhang et al., 2017). Similarly, the pollutants can also cause crop failure which affects food security and could lead to forced migration and related issues. Additionally, agriculture residue burning is a primary source of black carbon in Nepal (ICIMOD, 2020). Figure 12 illustrates some of the drivers for burning crop residues.

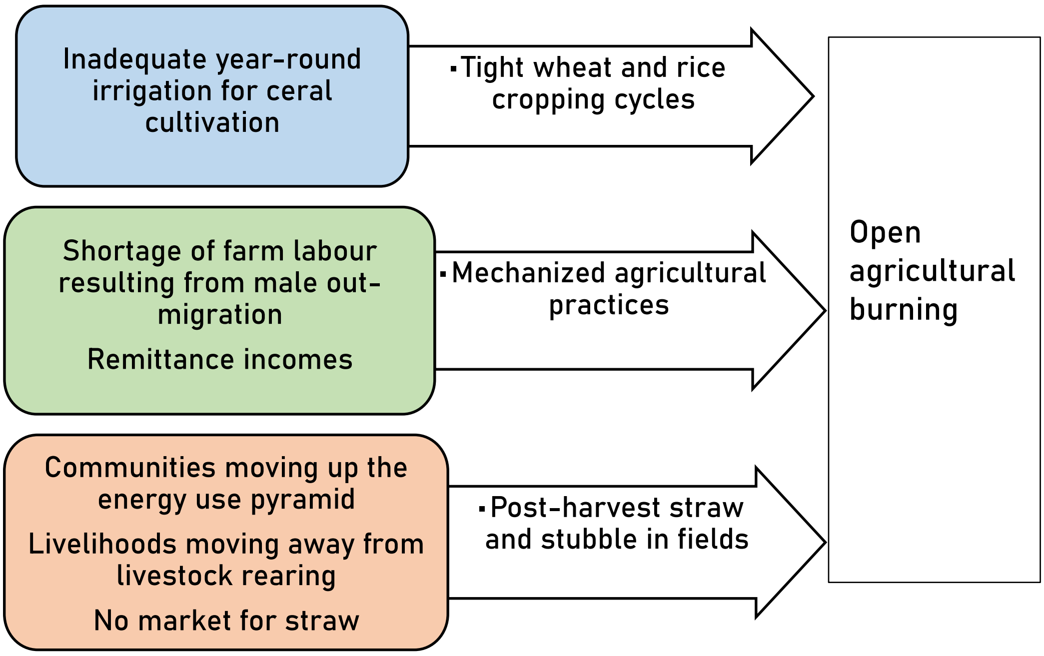


Figure 12: Drivers of crop residue burning
Source: ICIMOD, 2020

Agriculture residue burning is practiced in many countries especially during the harvesting season (Chang, Liu, & Tseng, 2013). The practice is similar in Nepal and the total emission from crop residue open burning in Nepal for 2016/17 are presented in Table 8 (Das et al., 2020). This study found that the air quality of Terai region (southern part of Nepal) is more susceptible to atmospheric pollution than the hill and mountainous regions due to agricultural residue burning. From the residual burning, each year about 7 Gg of NO_x, 2.7 Gg of NH_3 are emitted implicating human health and environment (Das et al., 2020).

Table 8: **Total emission from crop residue open burning in Nepal (2016/17)**

Parameters	Values (Gg/year)
CO_2	4140
CH_4	6.5
SO_2	1.2
$PM_{2.5}$	**24.5**
OC	48.6
BC	2.2
NOx	**7**
NMVOC	22.5
NH_3	**2.7**

Source: Das et al., 2020

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 policies from South Asia were collected and analysed by SANH. Assessing nitrogen-related policies helps to identify the gaps and opportunities for sustainably managing nitrogen in Nepal and in the South Asia region. An analysis of this kind provides an initial starting point to understanding what types of policies are in place followed by determining what is needed in the future to effectively and efficiently manage N_r. The policy assessment identifies the sectors and environmental sinks and the policy instruments that are suggested and/or are in place amongst other indicators for effective performance.

This work builds upon 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 have 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[8] with a total of 966 policies for South Asia. The policies were collected during 2020-2021. Table 9 provides an overview on nitrogen-relevant policies collected per country. Nepal's nitrogen-related policies contribute 11% to the overall policies collected for South Asia.

Table 9: 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 (Yang et al., 2021)

The policy documents collected include legislation, acts, laws, ordinances, plans, strategies, regulations, statute, standards, rules, orders, codes, frameworks, and guidelines. To ensure coverage of all nitrogen-related policy documents, relevant sectors and sub-sectors were identified namely: agriculture, land use, environment,

[8] SANH Database https://catalogue.ceh.ac.uk/documents/e2f248d5-79a1-4af9-bdd4-f739fb12ce9a

human health, marine, urban development, water and waste management, transport, energy, and industry. Within each country the ministries and commissions responsible for these sectors were also identified to assist the policy searches. For instance, not only ministries dealing with chemicals and fertilizers but also the less obvious ministries such as health were identified (see section 7. Stakeholder overview p 62). The policies were then filtered, classified, and analysed. Figure 13 provides an overview of the methods.

1.COLLECTION

- Nitrogen-relevant 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 policies (e.g., rules or regulations and/or a subnational policy), or an amendment (e.g. update to an existing policy). If it was an amendment it was assessed 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

3. CLASSIFICATION

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

4. ANALYSIS

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

Figure 13: An overview of the nitrogen policy assessment methods adopted by SANH

3.2 Policy classification

The collected nitrogen-related policies were classified based on certain characteristics to identify patterns in the types of policies in place for each country. Policies were classified by: environmental sink; sector; sub-sector; policy type; pollution source type; impact direction; relevance; and impact scope. The classification list is provided in Table 10. The classification approach followed closely to the global study approach used by Kanter et al. (2020), with additional classifications. For classification definitions see Appendix 1.

Table 10: **SANH nitrogen-relevant policy classification lists**

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

4 SANH nitrogen related policy dataset: Results for Nepal

4.1 Relevance & scope of policies

The nitrogen-related policies were classified according to their relevance and impact scope. These classifications were helpful for filtering policies with direct and/or indirect relevance to N_r management. Table 11 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.[9]

Table 11: Number and percentage of nitrogen-related policies in Nepal 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)	58	54	Large	**33**	31
Medium (indirect)	18	17	Medium	39	36
Low (indirect)	32	29	Small	36	33
Grand Total	108	100	Total	89	100

Data source: SANH database (Yang et al., 2021)

58 Policies (54%) were classified with direct and 'high' relevance for Nepal. Such policies included, for example, 'Environment Friendly Vehicle and Transport Policy, 2014, National Transport Policy 2001, National Agriculture Policy', 2004, and the 'National Environment Policy, 2019'.

Indirectly relevant policies with 'medium' relevance do not contain any 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. For Nepal, policies classified with medium relevance include, for example, Renewable Energy Subsidy Policy, (2073 BS) and Pesticides Act, 1991. A total of 18 policies (17%) were classified as having medium relevance.

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). 32 Policies (29%) were classified with low relevance, including, 'Seed Act, 1988' and the 'Forest Act, 1993'. Although they had no direct reference to nitrogen, they could still have implications on N_r management. For example, seed act is relevant due to impacts on yield which may influence agro-management decisions including fertilizer use.

Table 11 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. Policies classified with a

[9] The 29 key words were 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

'large' scope, a total of 34 policies (31%), include national level policies which have the potential to influence a large number of people. These are also more directly relevant to N_r management, such as the 'National Fertilizer Policy 2001', and the 'Organic and Biological Fertilizer Guideline, 2011' policy which have nation-wide implications for nitrogen fertilizer use.

39 Policies (36%) were classified with 'medium' impact scope including those which may be sub-national policies, or less directly relevant to nitrogen, including the 'Biomass Energy Strategy, 2017' and the 'Pesticide Act, 1991'.

The 36 policies (33%) classified with 'small' impact scope either focused on a very specific location or zone or were nationwide but with distant consequences towards N_r management. These include, for example, the 'National Biosafety Framework, 2007' and 'Ozone Depleting Substances Consumption (control) Rules, 2001'.

4.2 Policy types

Policy type, as a classification category, indicates the type of policy instruments 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) (see Appendix for classification definitions). For Nepal there were 174 classifications from the 108 policies. 43 Policies (40%) had more than one policy type identified. Policies with multiple instruments are favourable since they indicate a more comprehensive policy approach.

Table 12: Number and percentage of nitrogen-related policies in Nepal for policy type

Policy Type	Total no. of policies	% of classifications
Regulatory (a)	**11**	6
Economic (a)	**10**	6
Framework	**97**	56
Data and methods	**20**	11
R&D	**24**	14
Commerce	**7**	4
Pro-N	**5**	3
Grand Total	174	100

Data source: SANH database (Yang et al., 2021)

Table 12 illustrates the number and percentage of nitrogen-related policies in Nepal by policy type. The most common classification for policy type is framework (56%). Such policies often include those with broad objectives and/or designate governing bodies. For example, one framework policy is the 'National Fertilizer Policy, 2011'. The next most common classification is research and development (14%) like 'Agriculture Development Strategy (ADS) 2015-2035', followed by data and methods (11%) like 'National Adaptation Programme of Action 2010', whereas regulatory and economic policy types like 'Environment Protection Act, 2019' both individually occupy 6% of the classification. 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'.

The least common policy types featured in the dataset are commerce (4%) and pro-N (3%). An example of a commerce policy is 'Agri-Business Promotion Policy, 2006' whereas a pro-N policy includes the 'Nepal Agriculture and Food Security Country Investment Plan', 2010 which aims to enhance the supply of fertilizer both organic and inorganic.

4.3 Economic sector and sub-sectors

The economic sectors are classified based on whether they refer to one or more multiple sectors. Economic sectors include transport, energy, agriculture, waste, energy, industry, urban development and tourism, land use and change and food. Table 13 provides an overview of the total number of Nepal's nitrogen-relevant policies and percentages broken down by sector type. The most common classification of policies was for multiple sectors at 22%. This is an advantageous policy characteristic indicating that multiple sectors have roles to play in N_r management. Some policy examples include the 'National Environment Policy, 2019 and 'Environment Protection Act 2019'.

The second most common classification, as a single sector-oriented policy, is agriculture (19%) energy, at 8% followed by land use change (9%). The other main sectors each featured only as a small percentage of the overall policy collection (ranging from 1% to 6%). Lastly, a fairly high percentage (19%) of policies did not include any reference to a particular sector, i.e., the policy focused on one or more environmental sinks. Some examples include the 'Water Resource Act 1992 (2049 BS)' and 'Drinking Water Rules 1998 (2055 BS)'. While such policies should ideally be linked to sector actions, sink oriented policies are still considered positive because they focus on environmental protection and sustainability actions.

Table 13: Number and percentage of policies by sector in Nepal

Main Sector	No. of policies	% of policies
Agriculture	**21**	19
Energy	**9**	8
Food	**8**	7
Land Use Change	**10**	9
Other	**6**	6
Urban Development & Tourism	**1**	1
Industry	**1**	1
Transport	**5**	5
Waste	**3**	3
Multiple	**24**	22
No Sector Included	**20**	19
Grand Total	108	100

Data source: SANH database (Yang et al., 2021)

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 Annex 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 Nepal, the most common classification was where 'no sink' had been included in the policy text (43%). In other words, almost half of the policies collected were purely sector oriented. This could be regarded as an unfavourable policy characteristic as it indicates that such policies have not considered the potential risks, or options to mitigate negative N_r environmental impacts. Therefore, these policies represent a policy gap, that could be addressed through policy amendments. Such policies include the 'National Transport Policy, 2001' and the 'National Agriculture Policy, 2004'. Table 14 summarizes the number and percentage of policies for environmental sinks.

Table 14: Number and percentage of nitrogen-related policies in Nepal for environmental sinks

Sink	No. of policies	% of policies
Air	5	5
Climate	2	2
Ecosystem	16	15
Multiple	25	24
Soil	1	1
Water	12	11
No sink Included	47	43
Grand Total	**108**	**100**

Data source: SANH database (Yang et al., 2021)

However, the next most common classification was for multiple sinks (24%). This is considered a highly favourable characteristic as these policies address two or more sinks, acknowledging the interconnectedness of environmental systems, for example by addressing air and climate issues. Policy examples include the 'National Land Use Policy, 2015' and the 'National Environment Policy 2019'.

The most common single sink focus was on ecosystem (15%) followed by water (11%), including for example the 'Water Resource Act 1992' (2049 BS). The other single sink focused policies (either air, climate, or soil) had a low percentage of nitrogen-related policies associated with them (≤ 5%).

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 recognizing the difference between pollution type sources. Point source and non-point source (NPS) pollution policies 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 points', making it easier to control and monitor. Six policies were identified as 'point source'. Some examples include the 'National Indoor Air Quality Standards, 2009', and 'Nepal Vehicle Mass Emission Standards, 2012'.

NPS covers N_r pollution that comes from various land, air and/or water sources and with the possibility of being carried overland, underground, and/or into the atmosphere, making it difficult to measure and control (Islam et al. 2018; Liu et al. 2020). Only two policies were identified as having targeted and noted NPS, 'National Ambient Air Quality Standards, 2003' and 'Ozone Depleting Substances Consumption (Control) Rules, 2001'.

Although an environmental policy should recognize either point source or NPS, it is even more advantageous to consider both. This indicates a more comprehensive understanding of how N_r pollution can enter systems, recognizing different approaches needed to tackle them. For Nepal, 9% of the policies achieved this, including the 'Environment Protection Act, 2019 and Rules 2020'. Policies based on pollution type sources and their number and percentage are shown in Table 15.

Table 15: Number and percentage of nitrogen-related policies in Nepal for pollution type source

Pollution type source	No. of policies	Percentage of policies (%)
Point source	6	6
Non-point source (NPS)	2	2
Both pollution type sources	9	9
Unspecified	50	46
Non-applicable	41	38
Grand Total	**108**	100

Data source: SANH database (Yang et al., 2021)

However, more policies (46%) specified neither point source nor NPS. This could be a disadvantage for a policy's ability to support sustainable N_r management, especially as these policies are directly related to nitrogen.[10] The 'National Fertilizer Policy, 2011', 'National Agriculture Policy', 2004, National Environment Policy, 2019 were classified as unspecified. However, such policies could be amended to consider types of pollution sources, as appropriate.

Non-applicable was the most common classification (38%) 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 like 'National Biosafety Framework, 2007'.

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 collected require further scrutiny to determine effectiveness linking proposed objectives to actual impacts.

Table 16 shows that it was encouraging that 54% of Nepal's policies had a presumed positive impact, i.e., they should promote a reduction in N_r pollution and/or improved

[10] These policies were classified as having direct/high relevance to N_r, due to the inclusion of a key word.

nitrogen management whether directly or indirectly. This included environmentally oriented policies such as the 'Environment Friendly Vehicle and Transport Policy, 2014' and 'Ozone Depleting Substances Consumption (Control) Rules, 2001'.

Only a small number (5%) of policies were indicated to have a potentially negative impact, i.e., where environmental considerations were absent from the policy text. This is an unfavourable policy indicator as such policies may have the potential to increase nitrogen waste, by causing excess N_r. Policies classified as having a potentially negative impact include the 'Trade Policy, 2009'.

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). 41% 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. Further assessments of the mixed/neutral policy group would be needed to identify how far these policies could achieve sustainable outcomes.

Table 16: Number and percentage of Nepal nitrogen-relevant policies for impact direction

Impact Direction	No. of policies	Percentage of policies (%)
Mixed /neutral	45	41
Negative	5	5
Positive	58	54
Grand Total	108	100

Data source: SANH database (Yang et al., 2021)

4.7 Cross comparisons of classification for selected policies

Table 17 indicates the policies classified by relevance and impact scope. These 'selected' policies are assumed to have a greater impact on how N_r enters the environment (by having high-medium relevance and large-medium scope).

Those policies identified to have lower relevance and/or impact scope should, however, not be considered as irrelevant, as such policies still hold the potential to have an impact via amendments to consider and mitigate N_r waste. By removing those policies classified as having low relevance and/or low impact scope (omitting 43 policies, 39%) this leaves a total of 65 policies.

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

	Impact scope			
Relevance	**Large**	**Medium**	**Small**	**Grand Total**
High	28 (26%)	22 (20%)	8 (7%)	58 (54%)
Medium	4 (4%)	11 (10%)	3 (3%)	18 (17%)
Low	1 (1%)	6 (6%)	25 (23%)	32 (30%)
Grand Total	33 (31%)	39 (36%)	36 (33%)	108 (100%)

Note: cells highlighted indicate the 'selected' policies perceived to have higher relevance and impact scope.

Data source: SANH database (Yang et al., 2021)

As with the previous section the results below illustrate a cross comparison of two classification types. The following classifications are compared: pollution source and impact direction, sink and sector, and sector and sub-sectors with policy type.

4.7.1 Selected policies for pollution source and impact direction

Table 18 illustrates the pollution source type with the impact direction for the selected policies. Policies classified as positive have the largest percentage at 57% followed by mixed/neutral direction at 38%. However, 40% of all positive policies have unspecified pollution sources, including, e.g., the 'Climate Change Policy, 2019'. Such environmentally centred policies could be enhanced by amending them to consider the sources of pollution type, where suitable. Positive direction addressed 2% of NPS pollution and there were no policies classified as positive that addressed point source pollution. For mixed/neutral impact direction policies, the majority were classified as unspecified (20%), such policies may require attention to see how pollution sources could be more carefully considered.

Table 18: Percentage of selected Nepal nitrogen-relevant policies for pollution source and impact direction

Impact direction	Both	Non-Point Source (NPS)	Point Source	Unspecified	NA	Grand Total
Mixed /Neutral	6	0	3	20	9	38
Negative	0	0	0	3	2	5
Positive	8	2	5	40	3	57
Grand Total	14	2	8	63	14	100

Data source: SANH database (Yang et al., 2021)

4.7.2 Selected policies for sink and sector

Table 19 illustrates the selected policies comparing the classifications for sink and sector. The most common cross combination was the sector-based agricultural policies that did not consider sinks (15%). The next most common combination was for multiple sector policies with multiple sinks at 11%. This combination of features is assumed favourable for N_r management due to their indication of integrated objectives for sinks and sectors. Yet this result indicates a potential policy gap, as this means 89% of policies with high relevance to nitrogen (the overall majority) do not benefit from these integrated features.

Table 19: Percentage of selected Nepal's nitrogen-relevant policies for sink and sector

	Sink						
Sector	**Air**	**Climate**	**Ecosys-tem**	**Multiple**	**No sink included**	**Water**	**Grand Total**
Agriculture	0	0	0	6	15	2	23
Energy	0	0	0	2	9	0	11
Food	0	0	0	0	8	0	8
Industry	0	0	0	0	2	0	2
Land use change	0	0	2	6	0	0	8
Transport	3	0	0	0	3	0	6
Multiple	0	2	6	9	3	3	23
No sector included	3	2	2	2	0	5	12

Urban Development tourism	0	0	0	2	0	0	2
Other	0	0	0	0	2	2	3
Waste	0	0	0	0	3	0	3
Grand Total	6	3	9	26	45	11	100
Selected policies are based on high-medium relevance and impact scope, a total of 65 policies							

Data source: SANH database (Yang et al., 2021)

5 Cross comparatives policies

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 20 illustrates the sector and sink policy results. Most combinations had low percentages, i.e., ≤ 5%. One of the most common combination was for multiple sectors that refers to multiple sinks (10%). Policy examples include the 'National Environment Policy, 2019', and the 'Environment Protection Act, 2019'. These policies are favourable as they indicate 'integrated objectives' that consider multiple environmental aspects as well as multiple sectors.

The most common combination was 'No sink' and agriculture (13%), including for example the 'Nepal Agriculture and Food Security Country Investment Plan 2010'. Another common combination was 'ecosystem' sink focused policies with 'no sector included' (8%) such as 'National Wetland Policy, 2003'. In addition, another common combination was for policies that refer to 'other sectors' but have not considered sinks (5%). Any single sector focused policies that overlook sinks would benefit from further review and possible adjustments to mitigate negative environmental impacts.

Table 20: Percentage of nitrogen-related policies by sink and sector, from Nepal

	Sink							
Sector	**Air**	**Climate**	**Ecosystem**	**Multiple**	**No sink included**	**Soil**	**Water**	**Grand Total**
Agriculture	0	0	0	4	13	0	3	19
Energy	0	0	0	1	7	0	0	8
Food	0	0	0	0	7	0	0	7
Industry	0	0	0	0	1	0	0	1
Land Use Change	0	0	2	6	0	1	0	9
Multiple	0	1	5	10	5	0	2	23
No sector included	3	1	8	1	0	0	6	18
Other	0	0	0	0	5	0	1	6
Transport	2	0	0	0	3	0	0	5
Urban Dev. & Tourism	0	0	0	1	0	0	0	1
Waste	0	0	0	0	3	0	0	3
Grand Total	5	2	15	23	44	1	11	100

Data source: SANH database (Yang et al., 2021)

5.1 Policy by sink and policy type

Table 21 illustrates the sink and the policy type classifications for nitrogen-related policies from Nepal. From the results, most of the combinations of policy type and sink range from 0 to 5%. The most common combination (24%) was for framework policies that were sector oriented only (i.e., no sink included). Following this, framework policy types, with multiple sinks were the most common combination (14%). Multiple sinks also had a higher percentage (relative to other combinations) for economic (4%) and R&D (5%) policy types. Likewise, the ecosystem sink has a higher percentage (9%) with framework policy types.

R&D, with only sector-oriented policies, were also more common (5%). Lastly, the only single sink policy, water, with a slightly high percentage (5%), was associated with framework policy types.

These overall results illustrate that for any single sink-oriented policies there were no predominant policy types associated. Policies that refer to multiple sinks are most likely to be policies that include framework, and R&D aspects. Those policies with multiple sinks and having multiple policy types (14 in total) would be considered better suited for N_r management as they are considered to have more integrated objectives and approaches.

Table 21: Percentage of nitrogen-related policies by policy type and sink from Nepal

	Policy Type							
Sink	**Regulatory**	**Data & methods**	**Framework**	**Economic**	**R&D**	**Commerce**	**Pro-N**	**Grand total**
Air	2	0	1	0	0	1	0	4
Climate	1	0	1	0	0	0	0	2
Ecosystem	1	2	9	1	2	1	0	16
Multiple	1	4	14	1	5	1	1	26
No sink included	1	3	24	2	6	2	2	40
Soil	0	0	1	0	0	0	0	1
Water	1	2	5	2	1	0	0	11
Grand Total	6	11	55	6	14	4	3	100

Note: The percentage is calculated from the total number of classifications (i.e., 174) and not the total number of policies. This is because one policy could have multiple policy types.

Data source: SANH database (Yang et al., 2021)

5.2 Policy by sector and policy type

In Table 22, the classification for policy type and sectors are compared. The exception for single sectors includes 'agriculture' in relation to 'framework' type policy features as the second most frequent pair (11%) followed by land use change (6%) and food (5%). Similar to sinks, the category for 'multiple' sectors were also more commonly linked to certain policy types including, in descending order: framework, as the most common combination (14%), data and methods (5%), economic (4%) and R&D (4%) policy types. In 16% of policies no sector was included. The sector defined and associated with multiple sectors and having multiple policy types would be considered better suited for N management, 15 policies met these criteria.

Table 22: Percentage of nitrogen-related policies by policy type and sector from Nepal

Sectors	Policy Type							
	Regulatory	Data & methods	Framework	Economic	R&D	Commerce	Pro-N	Grand Total
Agriculture	1	2	11	2	4	1	2	21
Energy	0	2	3	2	2	0	0	10
Food	0	0	5	0	1	1	1	7
Industry	0	0	1	0	1	0	0	2
Land use change	1	0	6	0	1	1	0	8
Multiple	1	5	14	4	4	0	0	25
Other	1	1	3	1	1	1	0	9
Urban dev. & tourism	0	1	1	1	1	0	0	2
Transport	1	0	2	0	0	0	0	3
Waste	0	0	2	0	0	0	0	2
No sector included	2	1	9	2	1	1	0	16
Grand total	6	11	55	6	14	4	3	100

Data source: SANH database (Yang et al., 2021)

5.3 Policy sector, sink and policy type

In all of the above cross comparisons, policies that have included references to multiple sinks and/or sectors and include multiple policy instruments, stand out as being potentially well placed to support N_r management. From Nepal, 17 policies (16%) have multiple policy instruments and have either multiple sinks and/or sectors with medium to high relevance and impact scope for nitrogen. These polices are outlined in Table 23.

The policies that are considered the best placed to deal with N_r issues are those that meet 'all' those conditions and have multiple policy instruments, and multiple sinks, and multiple sectors, these however are more limited in number. There are 4 policies (4%) from the collection that met all these criteria included the 'National Adaptation Programme of Action (NAPA) to Climate Change, 2010' and the 'Water Resource Strategy, 2002'.

Table 23: Nepal nitrogen related policies that refer to multiple sectors, sinks and mixed policy types and classification for impact direction and pollution source type

	Policies	Impact Direction	Policy types
1.	National Environment Policy, 2019	UNSPECIFIED	POSITIVE
2.	Environment Protection Act, 2019	BOTH	POSITIVE
3.	Water Resource Strategy, 2002	UNSPECIFIED	POSITIVE
4.	National Adaptation Programme of Action (NAPA) to Climate Change. 2010	UNSPECIFIED	POSITIVE
5.	Agriculture Development Strategy (ADS) 2015 to 2035	UNSPECIFIED	MIXED /NEUTRAL
6.	Biomass Energy Strategy (2017)	UNSPECIFIED	MIXED /NEUTRAL
7.	Forestry Sector Strategy (2016)	UNSPECIFIED	POSITIVE
8.	National Urban Development Strategy 2017	UNSPECIFIED	MIXED /NEUTRAL
9.	Agri Business Promotion Policy, 2006	UNSPECIFIED	MIXED /NEUTRAL
10.	Agro biodiversity Policy, 2006	UNSPECIFIED	POSITIVE
11.	Priority Framework for Action of Climate Change Adaptation and Disaster Risk Management in Agriculture, 2011	UNSPECIFIED	POSITIVE
12.	Nepal National Biodiversity Strategy and Action Plan 2014-2020	UNSPECIFIED	POSITIVE
13.	Rural Water Supply Strategy, 2004	UNSPECIFIED	POSITIVE
14.	National Water plan 2005	UNSPECIFIED	POSITIVE
15.	Nationally Determined Contributions (NDC) 2016	UNSPECIFIED	POSITIVE
16.	Nature Conservation National Strategic Framework for Sustainable Development (2015)	UNSPECIFIED	POSITIVE
17.	Nepal Biodiversity Strategy, 2002	UNSPECIFIED	POSITIVE

Note: Policies highlighted in blue are those that include references to multiple policy instruments, multiple sinks and multiple sectors in their text.

In terms of recognizing pollution source types, which is also a desirable policy characteristic; from the 17 policies, one policy refers to both pollution types (NPS and point source) whereas the rest of the policies have unspecified pollution type. The policy that recognizes both pollution type is the 'Environment Protection Act, 2019'. All the 17 polices selected are classified as having a presumed positive or mixed/neutral impact on N_r.

5.4 Nitrogen related policies with time series

The number of nitrogen-related policies has been increasing over time. Most nitrogen-related policies (33%) were established within the year 2011-2019 followed by the policies established within 2001-2011 (31%). Table 24 illustrates policies established before 1990, between 1991-2000, 2001-2010 and 2011-2019 broken down by sector. Relatively, the classification for 'multiple' and 'agriculture' were the highest for all the years, with most policies established between 2011 and 2019.

Table 24: Number and percentage of Nepal's nitrogen-relevant policies before 1990 to 2019 (broken down by sector)

	No. of policies				% of policies			
Sector	>1990	1990-2000	2001-2010	2011-2019	>1990	1990-2000	2001-2010	2011-2019
Agriculture	2	6	7	4	2	6	6	4
Energy	0	1	3	5	0	1	3	5
Food	1	1	3	3	1	1	3	3
Land use change	0	5	1	4	0	5	1	4
Multiple	7	3	6	9	6	3	6	8
Other	1	0	6	5	1	0	6	5
Urban dev. & tourism	0	0	0	1	0	0	0	1
Waste	0	0	0	3	0	0	0	3
No sector included	6	6	8	2	6	6	7	2
Grand Total	**17**	**22**	**34**	**36**	**16**	**20**	**31**	**33**

Data source: SANH database (Yang et al., 2021)

In Table 25, the number of policies formulated before 1990, in 1991-2000, 2001-2010 and 2011-2019 broken down by sink are shown. Similar to other results, overall, more policies were formulated in 2011-2019. Here the results illustrate that policies without any reference to sinks were mostly established in 2001-2010 and 2011-2019 (total 33). The other classification that was most common for 2011-2019 was for multiple sinks (total 13).

Table 25: Number and percentage of Nepal's nitrogen-relevant policies before 1990 to 2019 (broken down by sink)

	No. of policies				% of policies			
Sink	>1990	1990-2000	2001-2010	2011-2019	>1990	1990-2000	2001-2010	2011-2019
Air	0	0	3	2	0	0	3	2
Climate	0	0	0	2	0	0	0	2
Ecosystem	6	5	2	3	6	5	2	3
Multiple	5	2	6	13	5	2	6	12
Soil	0	1	0	0	0	1	0	0
Water	1	5	6	0	1	5	6	0
NA	5	9	17	16	5	8	16	15
Grand Total	**17**	**22**	**34**	**36**	**16**	**20**	**31**	**33**

Data source: SANH database (Yang et al., 2021)

6. Overview of reactive nitrogen (N_r) emission trends and sector sources

6.1 Regional and national reactive nitrogen emission trends of key compounds

The major three reactive nitrogen (N_r) compounds of global concern include the Greenhouse gas (GHG) nitrous oxide (N_2O) and the two ambient air pollutants nitrogen oxides[11] (NO_x) and ammonia (NH_3). South Asia is a global hotspot for all three nitrogen compounds, with emissions above that of global levels (SANH & SANH 2022). Nitrogen oxide (NO_x) emissions have been increasing rapidly across South Asia and doubled since 2000. Electricity and heat generation is the main nitrogen oxide (NO_x) emission source, with 'road transport' and 'manufacturing and construction' also major regional contributors. Ammonia (NH_3) and nitrous oxides (N_2O) have also been increasing steadily with agriculture as a major source through managed soil and fertilizer use (SANH & SANH 2021).

In Nepal, similar patterns in the N_r emissions trends are evident. Figure 14 a-d illustrate the trends since 1970 for all three major N_r compounds nitrous oxide (N_2O) and nitrogen oxides (NO_x) and ammonia (NH_3) and for particulate matter ($PM_{2.5}$ and PM_{10}). This data is provided by the 'Emission Database for Global Atmospheric Research (EDGAR) 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 its analyses of the eight South Asian countries.

These data provide an overview into N_r emissions only. 'Emissions' refer to the production and discharge of substances into the air, especially pollutants as gas. Nonetheless, N_r enters the environment by a variety of sources and states, not only as atmospheric emissions but also through soils and water. For this report, we assess emissions which impact the air and climate, but also indirectly, due to nitrogen cascades, impact other sinks (Galloway et al., 2003).

[11]which includes nitrogen dioxide (NO_2) and nitric oxide (NO)

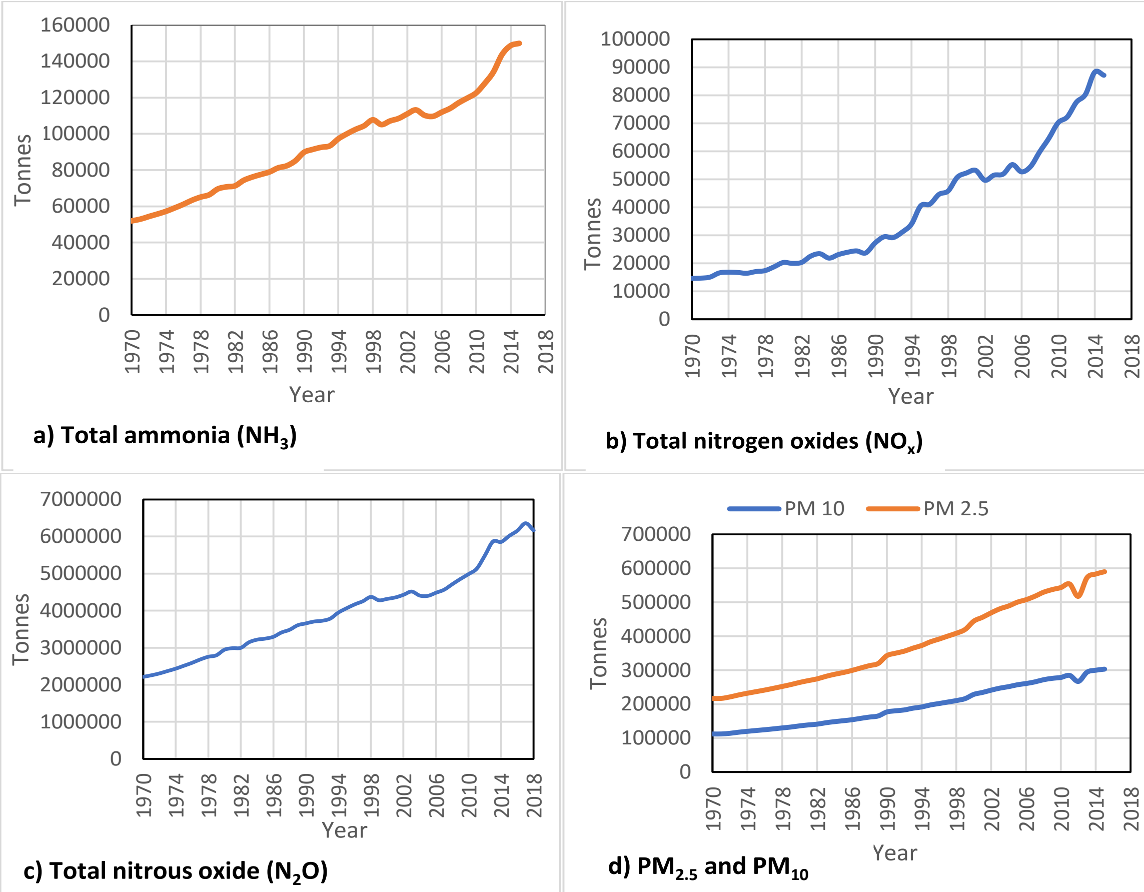


Figure 14: Nepal emission trends for ammonia (NH_3), nitrogen oxides (NO_x), nitrous oxide (N_2O) and $PM_{2.5}$ and PM_{10} from 1970 until 2015/2018

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

In Nepal, all three N_r compounds have been increasing over time. The same trends are visible for the particulate matters, $PM_{2.5}$ and PM_{10}. Table 26 and Figure 14 show that nitrogen oxides (NO_x), similar to what was found for South Asia, have had the steepest rise in the last decade. Table 8 highlights that from 2000 to 2015 nitrogen oxide (NO_x) emissions have had the highest increase (67% between 2000 and 2015).

Figure 14 further indicates steady increases of ammonia (NH_3) and nitrous oxide (N_2O) since the 1970's. Table 26, further illustrates that both compounds (NH_3 and N_2O) emissions have increased at a similar rate between the time periods 2000 to 2015 (by 40% and 43% respectively).

Table 26: Changes in emissions of key reactive nitrogen compounds, 2000-2015 for Nepal

	t/2000	t/2015	% Change
Ammonia - NH_3 emission (Gg/year)	107	150	40
Nitrogen oxides - NO_x emission (Gg/year)	52	87	67
Nitrous oxide - N_2O emission (Gg/year)	4318	6166*	43
*Note: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a) and EDGAR v6.0 Greenhouse Gas Emissions sourced by Crippa et al (2019b) *N_2O data is taken for 2018*			

6.2 National key reactive nitrogen emission by sources

The total N_r emission produced by sectors highlight where action is needed to address the main sources. Yet those sectors that have also had steep rises in emissions over the last decade also show 'emerging areas' where action is needed/or needs to be anticipated, to reduce N_r emissions to avoid further harm to people's health and the environment. Sectors that have had steep increases in recent years and also major contributors to overall emission are high priority areas for action to mitigate against N_r waste. This section breakdowns the drivers/sources of N_r emission in Nepal and compares the changes in emission levels.

6.2.1 Ammonia (NH_3)

Ammonia (NH_3) is a key pollutant contributing excess nitrogen deposition on vulnerable ecosystems (UNECE 2019) leading to acid deposition and eutrophication. Ammonia also features as a component of $PM_{2.5}$. Therefore, efforts to reduce ammonia directly would also have co-benefits for mitigating $PM_{2.5}$ pollutions (Wu et al. 2016).

In Nepal, in line with the regional results, agriculture is by far the largest contributor of NH_3 emissions (64%) to the overall total in 2015 and over the last few decades (Figure 15 and 16). The second largest contribution was from buildings as 35%, which includes small scale non-industrial stationary combustion whereas for the category 'other industrial combustion'[12] contributions were relatively small (0.45%).

Table 27 and 28 give a more detailed breakdown of the sector and sub sector sources. Sector sources for ammonia emission have changed to various extents. For all sectors, associated emissions have been increasing from 2000 to 2015 (Table 27) and ammonia emissions increased by 40%. Yet the biggest change was for transport[13] (700%) and power (100%) and these changes indicate that these are the fast-growing sectors. The only category that had remained unchanged and had no emissions in that time, according to the data, was for 'other' sectors[14] (0%).

The agriculture sector should be prioritized as it has a large overall contribution to emissions (Figure 16) and has a high rate of increase; however, the changes from 2000 to 2015 are comparatively lower (46%). Table 28 gives an overview of the sub sector emissions. Under agriculture 'direct emissions from managed soils' was the main emission source (70.96 Gg in 2015), followed by 'Other sectors' under Buildings (50.65 Gg), and then 'Manure management' (16.76 Gg) and 'Urea application' (4.62 Gg).

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

[13] Transport includes road transport, non-road transport, domestic aviation and inland waterways for each country. International shipping and aviation also belong to this sector yet are presented separately due to their international feature.

[14] Other sectors include industrial process emissions (non-metallic minerals, non-ferrous metals, solvents and other product use, chemicals), agricultural soils (urea fertilisation and lime application) and waste.

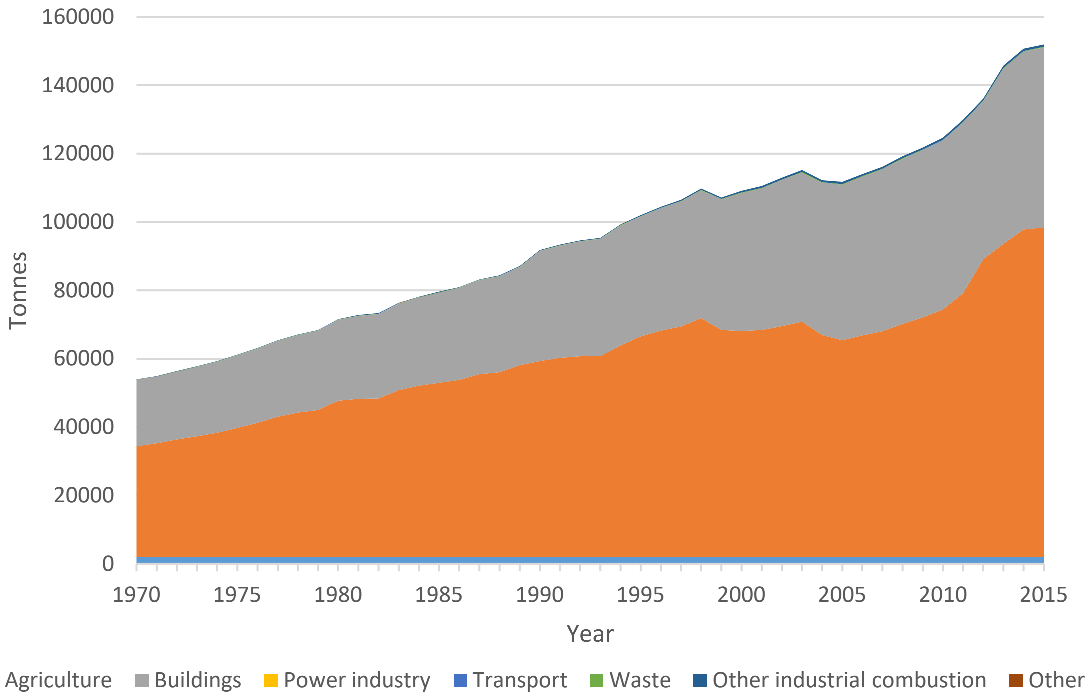


Figure 15: Trend in the NH_3 emission by sectors over the years in Nepal
Note: EDGAR v5.0 Global Air Pollutant Emissions data sourced from Crippa et al (2019a)

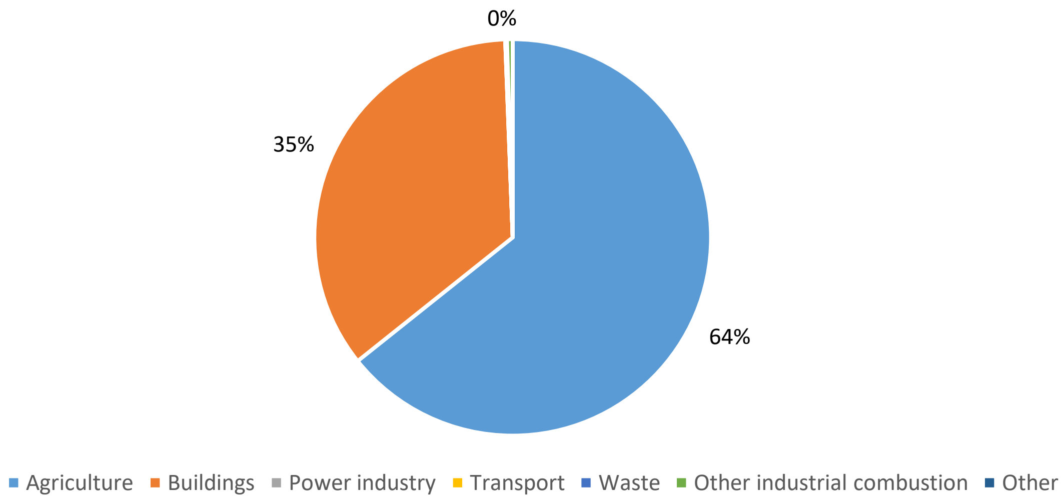


Figure 16: Ammonia (NH_3) emissions by main sector for Nepal in 2015

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

Table 27: Ammonia (NH_3) total emissions for 2000 and 2015 and percentage change for main sectors, in Nepal

Main sector sources	Tonnes/2000	Tonnes/ 2015	% change 2000 and 2015
Agriculture	66115	96378	46
Buildings	40362	52649	30
Power industry	1	0	100
Transport	5	40	700
Waste	147	179	22
Other industrial combustion	482	685	42
Other	0	0	0
Total NH_3	107112	149931	40

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

Table 28: Ammonia (NH3) total emissions for 2000 and 2015 (Gg [1]) and percentage change for different sub sectors in Nepal

IPCC	IPCC description for sub-sectors	Total emission Gg/ 2000	Total emission Gg/ 2015	% Change 2000 and 2015
Power Industry				
1.A.1.a	Main activity electricity and heat production	0.00098	NULL	-
Transport				
1.A.3.b_noRES	Road transportation no resuspension	0.0051	0.04	684
Buildings (energy)				
1.A.4	Other sectors	40.4	52.65	30
1.A.5	Non-specified	NULL	NULL	-
Other				
1.B.1	Solid fuels	0.13	0.20	54
2.B	Chemical industry	NULL	NULL	-
Other industrial combustion				
1.A.2	Manufacturing industries and construction	0.35	0.48	37
2.D	Non-energy products from fuels and solvent use	NULL	NULL	-
Agriculture				
3.A.2	Manure management	10.9	16.76	54
3.C.1	Emissions from biomass burning	3.62	4.05	12
3.C.3	Urea application	2.25	4.62	105
3.C.4	Direct N_2O emissions from managed soils	49.4	70.96	44
Waste				
4.C	Incineration and open burning of waste	0.038	0.05	32
4.D	Wastewater treatment and discharge	0.11	0.13	18
	Total NH_3	107.2	149.9	40

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

6.2.2 Nitrogen oxides (NO_x) emissions

Nitrogen oxides (NO_x) are one of the dominating polluting compounds globally and in South Asia. In contrast to ammonia, for nitrogen oxides (NO_x) agriculture is not the major contributor to overall emissions in Nepal. The main contributors of NO_x emissions include 'other industrial combustion' as the major contributor (32%). In a more detailed breakdown of this sector, it is evident that that 'Manufacturing Industries and Construction' is a major source of NO_x (28230 tonnes in 2015), see Table 29. The main sectors that are also major contributors of NO_x emissions include transport (27%) followed by buildings (25%) and agriculture (15%) as shown in Figure 18.

Steeper increases in nitrogen oxide (NO_x) emissions are noted between time period 2000 and 2015 (Figure 17), increasing by 67% (Table 26). Increases in NO_x emissions from agriculture have slightly increased (by 29%) over time compared to other sectors. In contrast Table 29 shows that the sectors with the biggest increases between 2005 and 2015 are for the transport (165%) and power industry (100%) and other industrial combustion (75%), followed by buildings (33%).

The sector breakdowns reveal for NO_x emissions from 'Road transportation' has undergone the highest change (165%) relative to other sectors between 2000 and 2015. Transport is also one of the biggest contributors to overall NO_x emissions at 27% in 2015, therefore should be a high priority area for tackling NO_x emissions in Nepal.

Manufacturing industries and construction is also the largest contributor to overall NO_x emissions in 2015 (75%), highlighting a priority sector where N_r mitigation is particularly important. For agriculture sub sectors for NO_x (<8 Gg in 2015) contributions were relatively lower compared to construction and transport but certainly represents an area that needs action given its major contribution to other N_r compounds (ammonia and nitrous oxide). 'Other' sectors' contributed overall a negligible amount to NOx emissions but increased by 33% and therefore should be monitored.

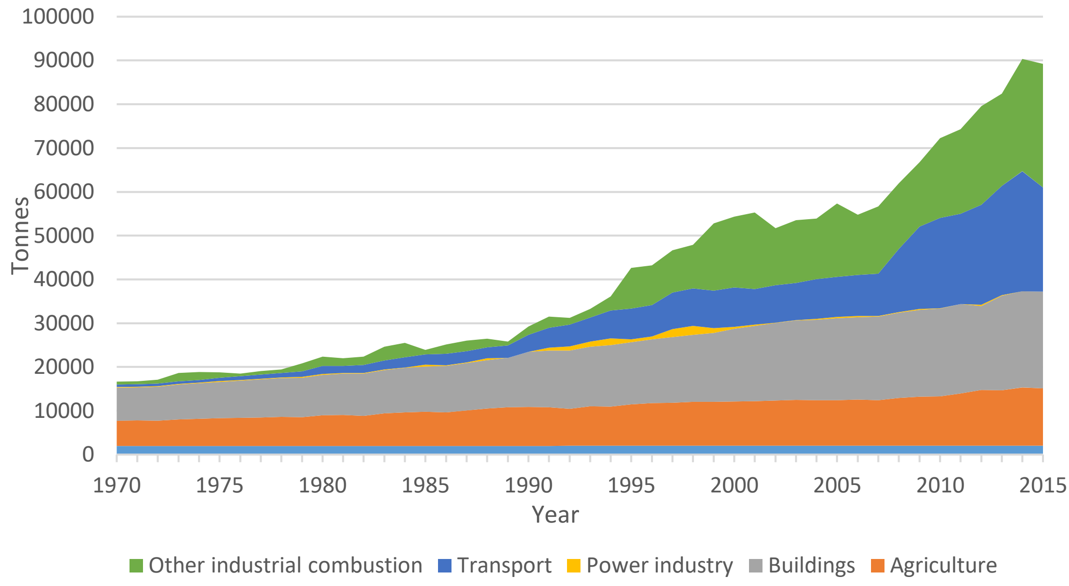


Figure 17: Trend in Nitrogen oxide (NO_x) emission by main sectors in Nepal

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

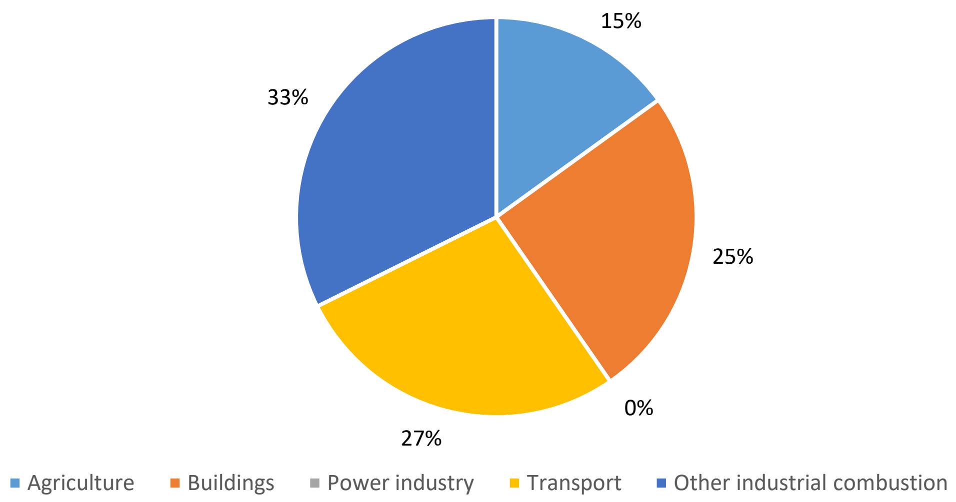


Figure 18: Nitrogen oxide (NO_x) emissions by sector for Nepal in 2015

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

Table 29: Nitrogen oxides (NO_x) total emissions for 2000 and 2015 and percentage change for main sectors, in Nepal

Sector sources	Tonnes /2000	Tonnes /2015	% Change
Agriculture	10153	13109	29
Buildings	16597	22093	33
Power industry	452	0	100
Transport	8981	23784	165
Other industrial combustion	16140	28230	75
Other	-	-	-
Total NO_x	52323	87216	67

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

Table 30: Total nitrogen oxides (NO_x) emissions in 2000 and 2015 (Gg) and percentage change for different sub sectors, Nepal

IPCC code	IPCC description for sub sectors	Total emission Gg/ 2000	Total emission Gg/ 2015	% Change 2000 and 2015
Power Industry				
1.A.1.a	**Main activity electricity and heat production**	0.45	NULL	-
Other industrial combustion				
1.A.2	**Manufacturing industries and construction**	16.1	28.23	75
1.B.1	**Solid fuels**	0.0021	0.003	43
Transport				
1.A.3.b_noRES	**Road transportation no resuspension**	8.98	23.78	165
Buildings				
1.A.4	**Other sectors**	16.6	22.09	33
1.A.5	**Non-specified**	NULL	NULL	-
Agriculture				
3.A.2	**Manure management**	0.64	0.89	39
3.C.1	**Emissions from biomass burning**	4	4.58	15
3.C.4	**Direct N_2O emissions from managed soils**	5.52	7.64	38
	Total NO_x	52.3	87.2	67

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

6.2.3 Nitrous oxide (N_2O)

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

For Nepal, and in line with results for South Asia as a whole, the largest contributor (87%) to nitrous oxide (N_2O) emissions is 'other sectors' in 2018, for N_2O 'other sectors' includes agricultural activities see Figure 19 and 20. A breakdown of sector emissions for nitrous oxide (N_2O) reveals the main source as 'direct N_2O emissions from managed soils'[15] (at 12.2 Gg year-1 in 2018) see Table 31. Managed soils include all soils on land, including forest land, which are under management (Hergoualc'h et al., 2019). 'Other sectors' also includes 'indirect N_2O emissions from managed soils', this was the second biggest contributor nitrous oxide (N_2O) (4.98 Gg year-1 in 2018).

In Nepal nitrous oxide (N_2O) emissions increased overall by 43% from 2000 to 2018 (Table 26). According to the aggregated sector categories, as in Table 30, in 'other sectors', covering agriculturally activities, emissions increased from 2000 to 2018 by 42%. The next biggest contributor of nitrous oxide (N_2O) emissions was the buildings

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

sector (12%) which increased by 39% from 2000. All other sectors, such as 'transport' and 'other industrial combustion' contributions to nitrous oxide (N_2O) emissions were minimal (e.g., <1%) in 2018 yet each had experienced large increases in emissions from 2000 (ranging from 72% - 668%).

For N_2O there were numerous sub-sectors where emissions had increased by over 40% from 2000 to 2018 but their overall contributions to emissions in 2018 were relatively small (<0%). Such as for 'Manure management' where N_2O emissions increased by 41% between 2000 and 2018 but only contribute 1.9% to overall emissions.

Sub-sectors that contribute the most to overall N_2O emissions in 2018, such as 'direct and indirect N_2O Emissions from managed soils', also increased since 2000 but by relatively smaller amounts (40% and 39% respectively). Yet as major contributors, and with these steady increases, land management indicates a priority policy area for tackling N_2O emissions. Likewise, 'wastewater treatment and discharge' and 'Indirect N_2O emissions from the atmospheric deposition of nitrogen in NO_x and NH_3', had an increase of 59 % and 71% respectively from 2000. In other sectors like Manufacturing industries and construction, Road transportation no resuspension contributes a relatively smaller amount to N_2O emissions in 2018 but had increases from 183% to 900% since 2000. This could be noted as emerging areas and indicates the need for monitoring these sub-sectors. Yet overall, the data highlights agriculture as the highest priority due to increasing and overall contributions, with priority policy areas in the Manufacturing and transportation sector too.

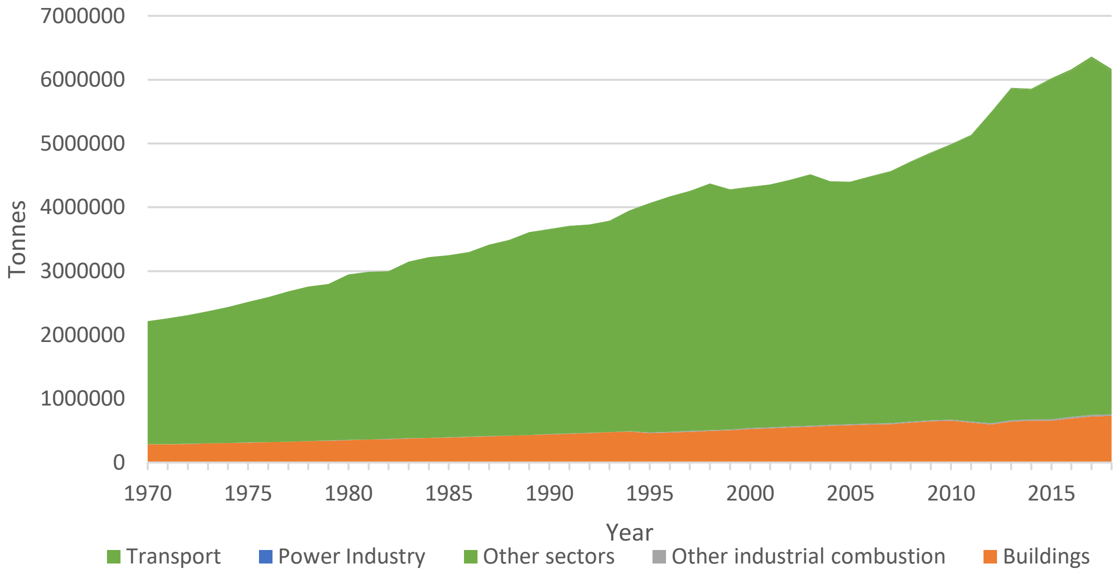


Figure 19: Nitrous oxide (N_2O) emission trends by sector sources in Nepal, from 1970 to 2018 *Source: EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b)*

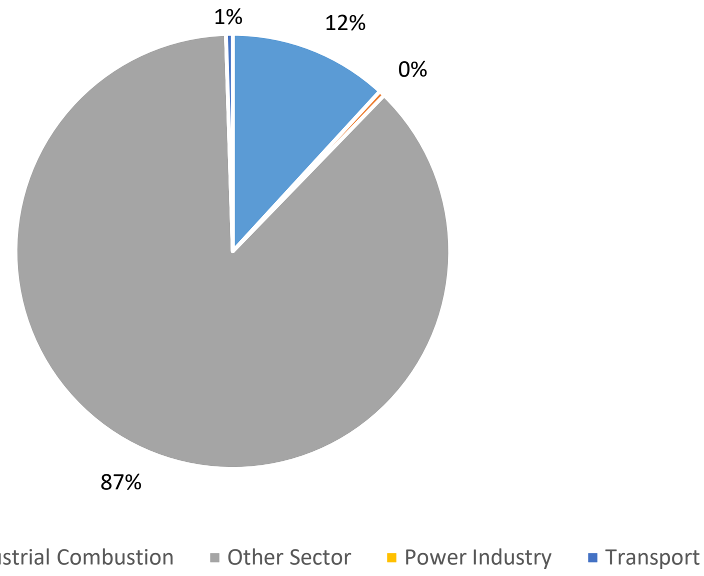


Figure 20: Percentage of nitrous oxides (N_2O) emissions by sector for Nepal in 2018
note: EDGAR v6.0 Greenhouse Gas Emissions data sourced from Crippa et al (2019b)

Table 31: Nitrous oxide (N_2O) total emissions for 2000 and 2018 and percentage change for main sectors, in Nepal

Main sectors	Tonnes/ 2000	Tonnes/ 2018	% Change 2000 and 2018
Buildings	523409	729568	39
Other industrial combustion	15013	26422	76
Other sectors	3776388	5379176	42
Power industry	48	0	-100
Transport	4017	30850	668
Total N_2O	4318875	6166016	43

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

Table 32: Total nitrous oxide (N_2O) emissions per sub sector between 2000 and 2018 (Gg per year) and percent change

IPCC code	Fossil_ or bio	IPCC description for sub sectors	Total emission Gg/ 2000	Total emission Gg/ 2018	% Change 2000 and 2018
Power industry					
1.A.1.a	fossil	**Main activity electricity and heat production**	0	0	0
1.A.2	bio	**Manufacturing industries and construction**	0.02	0.05	150
1.A.2	fossil	**Manufacturing industries and construction**	0.03	0.04	33
Transport					
1.A.3.b_no RES	fossil	**Road transportation no resuspension**	0.01	0.1	900
Buildings					
1.A.4	fossil	**Other sectors**	0.09	0.36	300
1.A.4	bio	**Other sectors**	1.66	2.09	26
1.A.5	fossil	**Non-specified**	NULL	NULL	NULL
Other Industrial Combustion					
1.B.1	bio	**Solid fuels**	0.00087	0.0014	61
2.G	fossil	**Other product manufacture and use**	0.007	0.0089	27
Agriculture					
3.A.2	fossil	**Manure management**	0.29	0.41	41
3.C.1	bio	**Emissions from biomass burning**	0.11	0.14	27
3.C.4	fossil	**Direct N_2O emissions from managed soils**	8.74	12.2	40
3.C.5	fossil	**Indirect N_2O emissions from managed soils**	1.82	2.53	39
5.A	fossil	**Indirect N_2O emissions from the atmospheric deposition of nitrogen in NO_x and NH_3**	0.73	1.25	71
3.C.6	fossil	**Indirect N_2O emissions from manure management**	0.12	0.18	50
Waste					
4.D	fossil	**Wastewater treatment and discharge**	0.85	1.35	59
		Total N_2O	14.48	20.71	43

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

6.3 National reactive nitrogen emission result summary

- The results on N_r emissions for Nepal indicate that all three N_r compounds of concern are on the rise and follow similar patterns to those identified for South Asia (SACEP & SANH, 2021).
- These results highlight that current policy efforts so far have not yet been able to mitigate or reduce N_r emissions. N_r emission levels will continue to increase unless further policy action is taken at international, national and local levels.
- Nitrogen oxides (NO_x) in Nepal are the fastest rising N_r compound, particularly since the year 2000.
- For ammonia (NH_3) and nitrous oxides (N_2O) the emission levels in Nepal have been increasing steadily, and at a somewhat similar pace since the 1970's.
- Agriculture is a major contributor to ammonia (NH_3) and nitrous oxide (N_2O). Whereas for nitrogen oxides (NO_x), the main contributor is the Manufacturing industries and construction. Yet agriculture is a common emission source for all three N_r compounds.
- The recent changes in N_r emissions also indicate where there have been increases and decreases between certain sector sources. These results highlight double threats for example from NO_x where the main sector source 'is the biggest contributor and has experienced the largest increases in emissions (67%) between 2000 and 2015.
- The changes in N_r emissions need to be considered with reference to the total contributions to identify emerging sectors where pro-active interventions are needed.
- The results indicate that different sectors contribute to the three N_r compounds in different ways. The overlap in sectors contributing to different compounds indicates areas where integrated policies are necessary to avoid pollution swapping and promote coordinated actions to mitigate excess N_r waste.

6.3.1 Ammonia (NH_3)

- For ammonia (NH_3), an ambient air pollutant, agriculture is by far the main pollution source (64% of total emissions in 2015), and emissions from this sector have been steadily increasing (by 46% from 2000 to 2015); measures for sustainable N_r management are urgently required.
- Under agriculture 'Manure management, Emissions from biomass burning, Urea application, Direct N_2O emissions from managed soils' contributes overall 64% to the NH_3 emission and were major contributors to overall emissions. Given emission are on the rise, policy should prioritize these agricultural sub sectors.
- The buildings sector is also an area of concern, as the next major contributor to overall ammonia (NH_3) emissions (at 35%), with increases (30%) from 2000 to 2015.

- Other sectors such as road transport had experienced higher increases of 700% from 2000 and 2015[16] but despite overall contributions to NH_3 emissions being minimal (0.03%) these sectors should also be monitored.

6.3.2 Nitrogen oxides (NO_x)

- For nitrogen oxides[17] (NO_X) an ambient air pollutant, there is a wider range of sectors (power industry, transport, other industry, agriculture, and buildings) that due to their overall NO_x emissions contributions and increases in recent years - require policy action to address N_r pollution.
- For NO_x, the area of main concern is 'Manufacturing industries and construction' which is a major source (28230 tonnes in 2015) contributing 32% to overall emissions in 2015 which also experienced rapid increases (75%) between 2000-2015.
- The next biggest contributor of nitrogen oxides (NO_x) is the transport sector (27%) and experienced a significant increase (165%) in the period between 2000-2015. Therefore, to tackle NO_x emissions the industrial sector followed by transport should be high policy priorities.
- For NO_x the sectors 'agriculture' and 'buildings' also underwent increases in the same time period but relatively smaller amounts 29% and 33% respectively. Yet these sectors still contribute to 15% and 25% respectively to overall NO_x and therefore should also be considered in N_r-related policy actions.

6.3.3 Nitrous oxide (N_2O)

- The largest contributor to overall N_2O emission comes from the sector categorized by EDGAR as 'other sectors', at 87%.
- 'Other sectors' for N_2O emissions include agricultural activities such as 'direct and indirect N_2O emissions from managed soils' which is indicated to be the largest sub-sector emission source (71%), and contributions have increased between 2000-2018 (39-40%). As a major emission contributor, land management is indicated as a priority policy area for tackling N_2O emissions.
- Likewise, 'Wastewater treatment and discharge' and 'Indirect N_2O emissions from the atmospheric deposition of nitrogen in NO_x and NH_3' have contributed to rising N_2O emissions and are further areas where N_r reductions are needed.
- Buildings as a main sector was indicated to be the next highest contributor to N_2O emissions at 12% in 2018.
- Manufacturing industries and construction and road transportation were minor contributors to overall N_2O emissions in 2018 (<1%) but emissions have been increasing by 150% and 900% since 2000. Such sectors require monitoring and mitigation measures considered to ensure N_r emissions do not continue to increase unabatedly.

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[16] Such as Road Transportation no resuspension that experienced a 5107% increase from 2000 to 2015.

[17] which includes (NO_2) and nitric oxide (NO)

7. Stakeholder overview

Stakeholders in this report are defined as individuals or groups who have an interest and/or potential influence on N_r management. This includes a wide range of actors due to the multi sector sources of N_r waste, along with its range of human and environmental impacts. Table 33 gives a preliminary overview into some of the main groups who may have a role in improving and addressing N_r management and on influencing policy. This includes government groups as well as non-government groups. SANH will continue to develop a better understanding of the nitrogen-relevant stakeholders over the course of the project.

Table 33: **Preliminary stakeholder overview**

Main groups	
Government	Three branches of government: Executive, Legislature and Judiciary. Ministries (Ministry of Forest and Environment, Ministry of Agriculture and Livestock, etc), Councils (Nepal Agriculture Research Council) and Committees. Government bodies: Nepal Electricity Authority (NEA), Municipal solid waste management (SWM) Community Mobilization Unit (CMU)
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, DFID[18], Japan International Cooperation Agency (JICA) Deutsche Gesellschaft fur Internationale Zuzammenarbeit (GIZ) GmbH ICIMOD (International Centre for Integrated Mountain Development) International Organization World Green Climate Association Winrock International, USA Water Aid Nepal Friends of the Earth Nepal
Regional partnerships	South Asian Association for Regional Cooperation (SAARC) South Asia Co-operative Environment Programme (SACEP)
Non-Government Organisations (NGOs)	Nepal Pollution Control & Environment Management Center Clean Energy Nepal Youth Alliance for Environment NGO Federation for Environment Conservation Nepal Kathmandu Environmental Education Project (KEEP) Save the Earth Foundation (SEF) ECO-Nepal Environmental Camps for Conservation Awareness (ECCA) Nepal Water Conservation Foundation (NWCF) Butwal Power Company Sustainable Agriculture Development Program (SADP)
Research and universities	Tribhuvan University Kathmandu University Pokhara University Purbanchal University Institute of Agriculture and Animal Science
Civil service organisations (CSOs)	Nepal Farmers' Association (NFA) Nepal Agriculture Co-operative Central Federation Limited (NACCFL)

[18] The UK Department for International Development was replaced by Foreign, Commonwealth & Development Office in 2019.

	National farmers Group Federation (NFGF) Clean up Nepal Lead Nepal
Community Based Organizations	Women's Group, Youth Group Nepal, Community Forest User Groups, farmer groups
Private companies	Organic Bio-Fertilizer Pvt. Ltd. Krishi Samagri Company Ltd, also known as Agriculture Inputs Company Ltd. (AICL) and Salt Trading Company Ltd. (STCL)

The following preliminary list of ministries includes all that are assumed to be key actors when it comes to N_r management and for policies related to agriculture, energy, transport and the environment:

- Ministry of Agriculture and Livestock Development
- Ministry of Forests and Environment
- Ministry of Land Management, Cooperatives and Poverty Alleviation
- Ministry of Education, Science and Technology
- Ministry of Water Supply
- Ministry of Industry, Commerce and Supplies
- Ministry of Urban Development
- Ministry of Physical Infrastructure and Transport
- Ministry of Culture, Tourism and Civil Aviation
- Ministry of Energy, Water Resources and Irrigation
- Ministry of Health and Population
- Ministry of Federal Affairs and General Administration
- Ministry of Law, Justice and Parliamentary Affairs

Ministries that may also be relevant in $N_{r,}$ but may not have direct impact, 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 Home Affairs
- Ministry of Finance
- Ministry of Women, Children and Senior Citizen
- Ministry of Education, Science and Technology
- Ministry of Labour, Employment and Social Security

The Councils are formed with ministry representatives, senior advisors, members of the government executive branch, with cabinet representatives, along with representatives from the private sector, civil society, and others. Those that are assumed to have relevance for N_r management include:

- Nepal Law Commission
- Nepal Agricultural Research Council (NARC)
- Nepal Academy of Science and Technology (NAST)
- Water and Energy Commission Secretariat
- Nepal Health Research Council
- University Grants Commission
- Social Welfare Council
- Federation of Nepalese Chambers of Commerce & Industry (FNCCI)
- Alternative Energy Promotion Centre (AEPC)
- National planning Commission

The 'Department of Environment' under the Ministry of Forest and Environment has a key role for managing national environmental issues, raising public awareness, applying a systematic approach to environmental monitoring and inspections and conducting environmental impact assessments according to the law.

Coordinating and Decision-making Committees

The following preliminary list of the coordinating and decision-making committees that have a role in N_r management in Nepal includes:

- National Planning Commission
- Agriculture and Water Resources Committee
- Environment Protection Committee
- Finance Committee
- Industry, commerce and consumer Welfare Committee
- Disaster Management Committee
- District Water Resource Committee
- Nepal-India Energy Secretary-Level Joint Steering Committee…

There are task forces that have been developed to address critical issues, such as the:

- Task Force on Air Pollution Control in Kathmandu Valley

8. Case studies of significant nitrogen control policies

This section provides an overview of three standout national policies for nitrogen management in Nepal. The three policies include the 'National Environment Policy 2019', the 'Environment Protection Act 2019' and the 'Agriculture Development Strategy 2015-35'. Table 34 provides detailed summaries of these three policies.

These three policies were selected based on their high relevancy and high impact scope for the N_r management. Policies that are high relevant to the nitrogen existing policies can also be adapted to deal with nitrogen more directly and effectively.

The 'National Environment Policy, 2019' (Table 33) was framed to guide the implementation of environment-related laws and other thematic laws, to realize international commitment and to enable collaboration between all concerned government agencies and non-government organizations on environmental management actions. The policy has specified special measures, including those to setup effective systems for checking and reducing pollution of all types, encouragement for the use of environment-friendly technology in industry, hospital and vehicles, regulation of harmful pesticides in production. This umbrella legislation aims to minimize pollution through setting out integrated objectives and policy approaches. It was classified as having addressed multiple sectors and sinks, advocating for a multi-sectoral approach.

Another standout policy includes the 'Environment Protection Act 2019' which replaced the 'Environment Protection Act, 1996'. This policy establishes that citizen should live in a clean and healthy environment, and, maintain a proper balance between environment and development, mitigate adverse environmental impacts on environment and biodiversity through different development activities and face the challenges posed by climate change. The policy binds the development activities through environmental assessment and focuses on environment protection. It has high relevance to pollution control and management. The policy was identified as having integrated objectives and approach with multiple sectors and sinks referred to in the text. The act authorizes the Government of Nepal to set standards to reduce and regulate emissions, hazardous waste, pollution emitted by vehicles, equipment, industries, hotels, restaurants and other institutions or activities. The act also addresses the concern of climate change and control of greenhouse gasses and other gasses, although it does not refer to any of the N_r compounds directly.

In contrast to the first two selected policies, which were driven by environmental goals, the main driver of the Agriculture Development Strategy (ADS) is to address the lack of anticipated growth and competitiveness of the agricultural sector. This policy presents an overall strategy, including a 10-year action plan and roadmap based on an assessment of the current and past performance of the agricultural sector in Nepal. The aim of the strategy is to generate higher productivity from the agricultural sector with effective agricultural research and extension, efficient use of agricultural inputs; efficient and sustainable practices and use of natural resources (land, water, soils, and forests); and increased resilience to climate change and disasters. Therefore, the strategy indicates attention to multiple policy instruments in order to meet policy goals. In addition, the policy objectives consider multiple sinks. Incremental time-bound quantifiable targets are provided to achieve soil fertility by increasing amounts of organic matter. Other measures include the promotion of organic manure and compost, green manuring, balanced use of chemical fertilizers, soil analysis service, etc. A subsidization strategy to supply organic and chemical fertilizer and other types of inputs and facilities is also provided.

Although none of these three policies address nitrogen management specifically they contain favourable features that have the potential to support effective nitrogen management practices, despite different primary focuses. All three policies have similar strengths, considering multiple environmental sinks and/or including multiple sectors and multiple policy instruments. However, whether these policies succeed depends on supporting legislation and resources for implementation.

Table 34: Case studies of the policies

Case Study I

Policy: title and year	**National Environment Policy, 2019**
Ministry responsible	Ministry of Forest and Environment
Policy objective	Minimize air, soil and water pollution Enhance cycling of nutrients of wastes and reuse them. Effective recycling of wastes and their use in agricultural production Lessen and prevent all types of environment pollutions, manage wastes emanated from all sectors including home, industry and service, expand parks and greenery in urban area and ensure environment justice to the pollution affected population
Classification e.g., for sink, sector, impact direction and relevance	Positive impact direction Direct and high relevance to nitrogen Multiple sector and multiple sink
Spatial scale	National
Policy type/s	Framework and R&D
Relevance to N: how this policy may directly/indirectly have an impact N management	Special measures, including the establishment of effective systems to reduce pollution of all types, the adoption of environmentally friendly technology in industry, hospitals, and vehicles, the use of harmful pesticides to avoid damaging human health and the prevention of use of unauthorized food products. Design a modern, environment-friendly method to handle dust, smoke and water pollutants coming from industries and other businesses. Promote the use of solar stoves, electric stoves, bio-gas, improved stoves and chimneys for pollution prevention in homes, and lay emphasis on energy efficient construction. There will be strategies in place to put into operation an integrated incineration machine which will manage wastes released from industrial establishments, hospitals, and other structures, encourage energy generation from waste, and manage explosive, poisonous, and perishable garbage.

Case Study II

Policy: title and year	**Environment Protection Act, 2019**
Ministry responsible	Ministry of Forest and Environment
Policy objective	Amend and consolidate the prevailing law on environmental protection in order to protect the fundamental right of each citizen to live in a clean and healthy environment, provide the victim with compensation by the polluter for any damage resulting from environmental pollution or degradation, maintain a proper balance between environment and development, mitigate adverse environmental impacts on environment and biodiversity and face the challenges posed by climate change;
Classification e.g., for sink/sector, impact direction	Multiple sector Direct and high relevance to nitrogen Positive impact direction
Spatial scale	National
Policy type/s	Data and methods, Framework, and R&D type
Relevance to N: how this policy may directly/indirectly have an impact N management	The act has also redefined certain terms so that the definitions are more comprehensive. For instance, "Pollution" has been redefined so as to include waste, chemical, heat, sound, electronic, electronic magnet or radioactive radiation that significantly degrade, damage the environment or harm the beneficial or useful purpose of the environment by changing the environment directly or indirectly. Further, the act explicitly authorizes the Government of Nepal to set standards to reduce and regulate emission, hazardous waste, pollution emitted by vehicles, equipment, industries, hotels, restaurants and other institutions or activities. The act also addresses the concern of climate change and control of greenhouse gasses and other gasses which was not addressed under the 1997 Act.
Other details	The environment protection act, 2076 (2019) has replaced the earlier environment protection act 2053(1997). The current act obligates the government of Nepal to recognise the sectors that produce greenhouse gas and mitigate its effects in the environment. Further, the act envisages the concept of carbon trading and empowers the government of Nepal to do carbon trading with foreign government and institutions. Act is a positive measure undertaken to improve the quality of life and the economy. The act explicitly authorizes the Government of Nepal to set standards to reduce and regulate emission, hazardous waste, Pollution emitted by vehicles, equipment, industries, hotels, restaurants and other institutions or activities. The act also addresses the concern of climate change and control of greenhouse gasses and other gasses which was not addressed under the 1997 act.

Case Study III

Policy: title and year	**Agriculture Development Strategy, 2015-35**
Ministry responsible	Ministry of Agriculture and Livestock development
Policy objective	Self-reliant, sustainable, competitive, and inclusive agriculture sector that drives economic growth and contributes to improved livelihoods and food and nutrition security leading to food sovereignty Increasing prosperity of farmers and agro entrepreneurs through higher incomes, improved livelihoods, and food and nutrition security
Classification e.g., for sink/sector, impact direction	Agriculture sector Direct and high relevance to nitrogen Positive and negative impact direction
Spatial scale	National
Policy type/s	Pro-N, Framework and R&D
Relevance to N: explain how this policy may directly/indirectly have an impact N management	Soil fertility: Focusing on soil fertility management, DOA is implementing the regular programs such as promotion of organic manure and compost, green manuring, balanced use of chemical fertilizers, soil analysis service, trainings, demonstrations, etc. Outputs on higher productivity: To improve the productivity and fertilizer use efficiency, promote organic/bio fertilizer as supplementary and complementary to chemical fertilizers, and facilitate effective distribution and supply to meet demand and public private partnership (PPP) program for availability of liquid nitrogen. Subsidies: Government is using subsidization as a strategy to address issues including: (i)supply of organic and chemical fertilizer; (ii) technology, seeds, poultry chicks and hatchery, fisheries, irrigation, equipment and tools; and (iii) agricultural production collection centre, warehouses, processing centre, cold storage and transport to remote areas.
Other details	Globally, there is growing concern and practice of improving food security and farmers' livelihoods through the sustainability of agricultural production systems. Traditionally, high investment and commercialized agricultural development have been used in preparing this strategy, neither of which is sustainable nor productive. It is directly related to labour issues, land and cultural changes, urbanization, land distributions, food imports, etc. However, these issues have not been analysed adequately and systematically, thus a re-analysis of the issues is necessary.

9. Needed actions

9.1 Increasing core policies on sustainable nitrogen management

Out of Nepal's 108 nitrogen-related policies, 28 were classified as being highly and directly relevant to nitrogen. Despite the number of policies that have direct relevance for N_r management in Nepal (26%), only a few policies refer explicitly to tackling nitrogen pollution or go as far as to refer to the N_r compounds (such as ammonia, nitrogen oxides and nitrous oxide). This is a policy gap that weakens their ability to address the rises in N_r waste directly. Therefore, **it is recommended that adjustments to existing directly nitrogen-relevant policies are made to recognize N_r sources and impacts explicitly, ideally specifying the nitrogen compound/s, to improve their effectiveness in addressing N_r waste**. In addition, having this **direct reference to N_r, will help with anticipating key sources and impacts in future nitrogen-related policy development.**

Likewise, only a few policies have regulatory and/or economic features (10% of all policies). Such policies are considered 'core nitrogen policies' as they directly address nitrogen production, consumption or loss in a measurable way' (Kanter et al. 2019). Therefore, there is scope to modify existing policies and to introduce new ones to feature regulatory and/or economic instruments to provide quantifiable limits and/or incentives to support sustainable N_r management directly. For instance, the Industrial Policy, 2011 mentioned measures to be taken for promoting green industries and to make the established industries pollution-free and also to make reduce carbon emission to zero, but it has not mentioned nitrogen emissions that are an additional kind of threat in the environment.

In addition to **addressing nitrogen management systematically, such policies should also be accompanied by more direct actions, via 'core' policies, that will facilitate and encourage efficient and effective N_r management. Overall, more action needs to be done to set quantifiable and enforceable constraints on N production, consumption in Nepal.**

The difference and similarities between the pollution sources and impacts between the N_r compounds should further be recognized. Nitrogen oxide (NO_x) emissions were identified as being the most problematic of the three N_r compounds (in terms of growth at 67% between 2000 and 2015 and overall contributions). Ammonia emissions (NH_3) are the highest in overall contributions and have increased by 40% since 2000. That said all three compounds have increased over time. The findings indicate the overlap and divergences in sources for the different compounds. Nonetheless **nitrogen compounds should not be dealt with in isolation from each other**. Mitigation measures for one N_r compound may cause a negative knock-on effect on other compounds. **Therefore, efforts to address one sector and a compound need to take into account all impacts on other N_r compounds to mitigate any unintended feedbacks.**

9.2 Amendments to existing policies

To deal with the nitrogen management, **existing policies can also be adapted to more directly/effectively address N_r management**. For instance, policies such as 'National Nutrition Policy and Strategy, 2004', 'Pesticides rule, 1994' classified as having medium to low relevance often do not refer to nitrogen directly but can still have implications to its management. It is within these policies that minor amendments could be applied in order to address nitrogen. For example, legislation related to food could go further to consider the nitrogen footprint in the food chain, and organic fertilizers containing low quantity of nitrogenous compound could be used.

9.3 Need for more holistic and integrated policies

Unless a broader framework and understanding of nitrogen production are used, referring to only to a single sink or sector can limit the effectiveness of the policy. In Nepal, nearly half of policies reference sinks indicating a positive approach to nitrogen management by considering environmental concerns and/or protecting the environment. However, 36 policies are just focused on one sink. Likewise, there are 47 policies that focus only on sectors, and do not consider the environmental sinks, and 47 policies focus only on a single sector. In the agriculture sector, for instance, the database lists policies are specific to only one sector, whereas most policies related to agriculture do not mention sinks.

Therefore, it is recommended that policies should aim to feature references to at least one sink, ideally multiple sinks. Likewise, policies should link to sector sources, and ideally across multiple sectors in order to have integrated approaches to N_r management objectives.

Having multiple policy instruments such as regulations, economic incentives, data and methods, R&D etc. is further beneficial. Policies with multiple instruments are regarded as more comprehensive. The Intergovernmental Panel on Climate Change (IPCC), amongst others, advocate for adopting a combination of policy instruments in order to secure better environmental outcomes than is possible from individual policy instruments (Gupta et al., 2007). Only few polices such as, 'National environment policy, 2019', and 'Environment Protection Act, 2019' described in the case study section were identified in the policy collection that meet these the criteria for multiple policy types, sectors and sinks. While it would not be suitable for all policies to have all these features there is certainly scope to increase the number that do.

9.4 Nitrogen fertilizer management: Moving towards sustainability

With commercialization of agriculture in Nepal, demand for agro-chemicals has been continually increasing. The annual average fertilizer requirement in Nepal to replenish the soil nutrition is 310 kg per hectare but only 29 kg of fertilizer is added to the soil (Ghimire, 2008). Most N fertilizer inputs are not used by crops and end up in the environment through emission gases and/or the pollution of water sources (Martínez-Dalmau et al., 2021). However, present supply of chemical fertilizer in Nepal is not meeting its demand (Panta, 2018). Therefore, alternative measures can save considerable revenue, maintain soil, environment and human health, examples include:

- improvement of Farm Yard Manure (FYM),
- promotion with subsidy in the field of organic manure use and production,
- modification in the agriculture practices like proper intercropping with legumes, appropriate application method of recommended nitrogen fertilizer dose

Along with these measures, effective enforcement of quality control standards at the point of sale with enough human capacity is recommended at the government level. In this context, government and importing organizations must lay focus on timely supply even more than to subsidy. Integrated nutrient management (INM) should be practiced and promoted by the government for enhancing sustainable nitrogen fertilizer management. In the field of agriculture development, the management of nitrogen fertilizer reform and regulatory change are needed.

9.5 Strengthening global commitment

Nepal's is continuing its support for global actions for sustainable nitrogen management. Nepal is one of fourteen countries that committed to the Colombo Declaration in November 2019, which supports a 'Global ambition to halve nitrogen waste by 2030'. In addition, Nepal co-sponsored the draft resolution UNEA-5.2 on sustainable nitrogen management, was adopted by UNEA in March 2022. The resolution encourages the development of National Action Plans to sustainably nitrogen management according to national circumstances. Nepal has committed to the preparation of an action plan. **The continued strengthening of Nepal's national, regional and international commitments to manage nitrogen sustainably, will highlight the country's leading dedication to find and adopt solutions posed by the nitrogen challenge.**

9.6 In-depth research

All the nitrogen-related policies collected would benefit from further scrutiny to determine their effectiveness, their actual impacts on Nr management, such as identifying whether a policy may contribute to point source, or non-point source pollution, or both. Likewise, it is important to evaluate further the barriers and opportunities for addressing Nr waste in current policy. Further in-depth research on the impact of policies and stakeholders related to Nr management would further support policy development. SANH will continue researching policies and stakeholders over the course of the project (2022-24) to improve national and regional level understanding of the nitrogen policy landscape. Furthermore, having research and development (R&D) as a policy instrument within nitrogen-related policies is recommended, this was referred to in only 14% of the policies.

9.7 Science-based decision making

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

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Appendix

Appendix 1: 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, a single policy could be coded under one or more of these codes as appropriate.*	Regulatory	Policies that set quantifiable limits or restrictions on N production, consumption and loss. This could also include broader strategies if they include quantifiable targets that could have impacts on N management.
	Economic	Policies that use financial incentives and signals to spur quantifiable improvements in N management and N mitigation'. Following Kanter et al. (2020) *regulatory* and *economic* policies were classified as 'core' policies, i.e., those most likely to have an impact on N production, consumption of management.
	Framework	Broad objectives relevant to N pollution with no quantifiable constraints and/or delegation of authority for N policymaking to another governing body'. A number of indirectly relevant policies fell under this definition. For example, it could be a regulatory policy, but in the absence of direct quantifiable constraints on nitrogen it would be classified as a 'framework' as in the case of the Regulations on Safe Food (Healthy Environment Protection), from Bangladesh.
	Data and methods	Those that 'establish data collection and reporting protocols for various aspects of N pollution but do not set environmental standards or enforce them'. This would also include standards (which could in addition be classified as regulatory).

		Policies that refer to an objective and/or actions for Monitoring and evaluation (M&E) were also classified under this
	Research & Development (R&D)	Policies that allocate funding for R&D both into the effects of N pollution on the environment and human health and into new technologies that could improve N management'. A policy could be classified under this code if it referred to promoting research in the text and that research relates to N related practices
	Commerce	Policies that regulate an aspect of the business environment surrounding N production and consumption'.
	Pro-N	Policies that lower the price of N production and consumption via government aid or other means, usually incentivizing higher farmer-level N use'
Pollution type	Point source	*Point source pollution* is where nitrogen pollution is discharged directly into water or into the atmosphere at a 'discrete point', making it easier to control and monitor. A policy would be classified as this if it states actions to target/control/measure point source pollution.
	Non-point source	*Non-point sources* cover pollution that comes from many land, air or water sources and can be carried overland, underground, or in the atmosphere, making them difficult to measure and control (Islam et al. 2018; Liu et al 2020). A policy would be classified as this if it states actions to target/control/measure non-point source pollution.
	Both	Policies refer targeting both point and non- point source pollution
	Unspecified	For policies that do not reference or 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 words were used to identify policies, i.e., if the policy contained one or more of these listed key words[19].
	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.

Appendix 2: Intercensal population changes (1911-2011) A.D.

Census year	Population	Intercensal changes (%)	Annual exponential growth rate (%)
1911	5,638/749	-	-
1920	5,573,788	-1.15	-0.13
1930	5,532,574	-0.74	-0.07
1941	6,283, 649	13.58	1.16
1952/54	8,256,625	31.40	2.28
1961	9,412,996	14.01	1.64
1971	11,555,983	22.77	2.05

[19] **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.

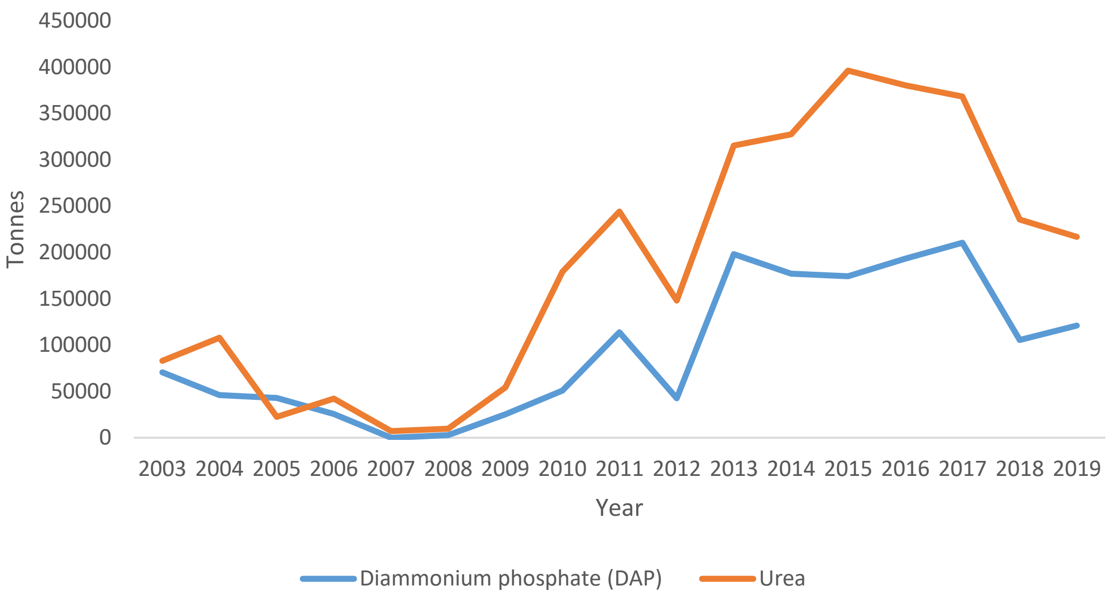
1981	15,022,839	30.00	2.62
1991	18,491,097	23.09	2.08
2001	23,151,423	25.20	2.25
2011	26,494,504	14.44	1.35

Source: CBS, 2012

Appendix 3: National ambient air quality standard, 2012 (NAAQS)

Parameters	Units	Averaging time	Concentration max	Test methods
TSP	µg/m^3	Annual	-	
		24-hours	230	High Volume Sampling Analysis and Gravimetric Analysis
PM_{10}	µg/m^3	Annual	-	
		24-hours	120	High Volume Sampler and Gravimetric Analysis, TOEM, Beta Attenuation
Sulfur Dioxide	µg/m^3	Annual	50	Ultraviolet Fluorescence, West and Gaeke Method
		24-hours	70	Same as annual
Nitrogen Dioxide	µg/m^3	Annual	40	Chemiluminescence
		24-hours	80	Same as annual
Carbon Monoxide	µg/m^3	8 hours	10,000	Non-Dispersive Infra-Red spectrophotometer (NDIR)
Lead	µg/m^3	Annual	0.5	High Volume Spraying, followed by atomic absorption spectrometry
Benzene	µg/m^3	Annual	5	Gas Chromatographic Technique
$PM_{2.5}$	µg/m^3	24-hours	40	$PM_{2.5}$ sampling gravimetric analysis
Ozone	µg/m^3	8-hours	157	UV spectrophotometer

Appendix 4: Agricultural use of synthetic fertilisers (Urea and DAP) in Nepal from 2002 – 2019 (Source: FAOSTAT, 2020)



Appendix 5: Manure applied to soils (N content) in Nepal from 1961 to 2019 (Source: FAOSTAT 2022)