UKRI GCRF South Asian Nitrogen Hub

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Nitrogen Management in Indian Agriculture: Policy Perspectives and Stakeholder Research

Final Report

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List of Acronyms

CBD	Convention on Biological Diversity
CCEA	Cabinet Committee on Economic Affairs
CII	Confederation of Indian Industry
CPCB	Central Pollution Control Board
CPDO	Central Poultry Development Organisation
CSIR	Council of Scientific and Industrial Research
CSOs	Civil Society Organisations
DoAC	Department of Agriculture & Cooperation
DBT	Department of Biotechnology
DoF	Department of Fertilisers
FCI	Food Corporation of India
FGD	Focus Group Discussions
FICCI	Federation of Indian Chambers of Commerce & Industry
GEF	Global Environment Facility
GHG	Greenhouse Gases
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
IFFCO	Indian Farmers Fertiliser Cooperative
IIT	Indian Institutes of Technology
ING	Indian Nitrogen Group
INI	International Nitrogen Initiative
INMS	International Nitrogen Management System
INSA	Indian National Science Academy
KRIBHCO	Krishak Bharati Cooperative Limited
KVKs	Krishi Vigyan Kendra's
MANAGE	National Centre for Management of Agricultural Extension
MoAFW	Ministry of Agriculture and Farmer Welfare
MoCF	Ministry of Chemical and Fertilisers
MoCAFPD	Ministry of Consumer Affairs, Food and Public Distribution
MoEFCC	Ministry of Environment, Forests and Climate Change
MNRE	Ministry of New and Renewable Energy
MoPNG	Ministry of Petroleum and Natural Gas
MSP	Minimum Support Prices
N	Nitrogen
NAAS	National Academy of Agricultural Sciences
NABARD	National Bank for Agriculture and Rural Development
NARS	National Agricultural Research System
NCR	National Capital Region
NCOF	National Centres of Organic Farming

NDDB	National Dairy Development Board
NDRI	National Dairy Research Institute
NGOs	Non-Governmental Organisations
NGT	National Green Tribunal
NPOF	National Project on Organic Farming
N_r	Reactive Nitrogen
PFO	Public Funded Organisation
PGS	Participatory Guarantee System
RPS	Retention Pricing Scheme
SACEP	South Asia Co-operative Environment Programme
SAU	State Agriculture Universities
SCON	Society for Conservation of Nature
SHGs	Self Help Groups
SPCB	State Pollution Control Board
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme

Executive Summary

South Asian countries are significant contributors to global reactive nitrogen (N_r). These nations include Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. While nitrogen is an indispensable nutrient that fuels agricultural and food production, its excessive use has become an alarming environmental issue. Although nitrogen plays a crucial role in complex ecological systems, human activities—such as agriculture, transportation, industry, energy production, and waste management—have altered the nitrogen cycle in ways that now harm ecosystems. It leads to the release of pollutants such as ammonia, nitrous oxide, nitrites, and nitrates into the air and water.

Despite these consequences, policy attention in this region towards reactive nitrogen remains noticeably weaker compared to carbon emissions. For instance, in India, most related policies have focused narrowly on 'farmers', neglecting the broader 'agriculture food supply chain'. This emphasis might contribute to the existing policy vacuum surrounding the nitrogen issue. This situation is exacerbated by the siloed approaches of various government ministries and agencies, each regulating distinct sectors and resulting in fragmented or disjointed policy responses.

To effectively address these challenges, a comprehensive policy integration assessment is critical in the study of environmental policy. Consequently, stakeholder research becomes indispensable for analysing policy contexts and evaluating implementation strategies under these complex situations.

The objective of this research was:

1. To identify key stakeholders within the Indian agricultural sector
2. Analyse their perspectives on nitrogen management-related policy decisions
3. Explore opportunities for enhanced engagement towards more sustainable Nitrogen management.

The report provides a comprehensive narrative of the stakeholder analysis process, underpinned by robust literary evidence and expert consultations. This analysis meticulously examines policy contexts and stakeholder dynamics by employing qualitative, multi-stage, and multi-dimensional methodologies. At the national level, the study concentrates on four pivotal areas for managing nitrogen in agriculture: fertiliser reforms, promoting organic and sustainable practices, crop residue management, and livestock feed and waste management strategies.

To inform this analysis, the full-chain nitrogen use efficiency concept was adapted and employed to develop a framework. This framework is designed to identify key decision areas pertinent to nitrogen management policies, as well as the stakeholders who influence and are impacted by these policy decisions. The analysis was conducted in three distinct stages: policy identification, policy analysis, and stakeholder analysis. The latter encompassed stakeholder identification, interest-influence mapping, categorisation, and engagement strategies. Data collection involved a desk review of key policies and relevant literature to map key debates, stakeholders, their interests, influences, and policy barriers. This was complemented by empirical data collection through expert interviews, focused group discussions, and stakeholder interviews.

The findings reveal that the dynamics among various stakeholders in the agricultural sector are complex and multifaceted. These stakeholders encompass local participants, including farmers, consumers, and farmer unions; market actors, such as processing industries, manufacturers, retail

organisations, input suppliers, and financial institutions; and government actors, including ministries, departments, extension agencies, research organisations, judicial bodies, financial institutions, and international agencies.

A significant driver for the renewed interest in sustainable agricultural reforms across these groups appears to be the observed decline in agricultural output and environmental health in certain areas, attributed to factors such as excessive use of chemical inputs and diminishing soil fertility. This landscape of stakeholders is broad, involving various ministries and government departments at both the central and state levels, universities, research centres, and NGOs, among others. While central government policies often exert significant influence over the agricultural sector, state governments hold equal authority in policy decisions and their implementation, typically through extension agencies. Research institutes are widely recognized for providing valuable scientific input, but their direct participation in decision-making processes has been limited, especially compared to counterparts in other nations.

Within the market actors, fertiliser businesses and other participants generally advocate for reforms that would optimize their financial benefits. However, the findings also highlight this group's notable and growing environmental consciousness. Civil society actors, such as NGOs, farmer associations, and the media, are often vigorous advocates for sustainable practices. However, according to the findings, their participation in the policy-making process remains relatively limited.

Further, the interest-influence matrix investigated the stakeholder impact on crucial policy decisions. The classic two-by-two matrix was expanded into a three-by-three matrix to incorporate the nuanced perspectives of diverse stakeholders and clearly categorize them based on their interests and ability to influence decisions at various times. Based on the shared or diverging interests and influence of the stakeholders, nine analytical stakeholder types were identified and later defined: Subjects, Promoters, Key Players, Marginal Actors, Latent Actors, Potential Supporters, the Crowd, Low-priority Actors, and Context Setters. The positions of these stakeholders varied in relation to the policies and agriculture sub-sectors in question, showing that they were neither fixed nor independent from those of other stakeholders. Based on the greater clarity in stakeholder category definitions, the stakeholder engagement approach was better informed to garner policy attention and reforms towards sustainable natural resource management.

Further, in focus group discussions, we discussed how experts perceive stakeholders could shift their positions in the future to impact policy results for pushing forth the agenda of sustainable nitrogen management in the agriculture sector. During stakeholder engagement, we reviewed policy barriers and challenges with key stakeholders at two levels: the current policy enabling environment, and the gaps in policy changes in advancing respective Nitrogen management objectives together with plausible opportunities to overcome them.

Thus, the current analysis seeks to broaden policy prospects by identifying stakeholders, their roles, their interests, and their level of influence across the agriculture food supply chain; in doing so, the policy regime engaging these stakeholders at different levels might aid in addressing the nitrogen management challenge.

Report Overview

The report, 'Nitrogen Management in Indian Agriculture: Policy Perspectives and Stakeholder Research', focuses on stakeholder research carried out by the UKRI South Asian Nitrogen Hub (SANH) team at The TERI School of Advanced Studies (TERI SAS). Drawing on the SANH regional policy database, the study maps global and national policy shifts in nitrogen management regimes, identifies major stakeholders, analyses their positions on N management-related policy decisions in India, and suggests ways to improve N management.

The research objectives for stakeholder analysis are:

- To understand the existing N policy regime (international and national level policies/conventions, key debates, and critical decisions concerning N management)
- To identify key policies and stakeholders with significant relevance to N management in Indian agriculture
- To identify the roles, interests, and influences of the identified stakeholders
- To engage with key stakeholders on emerging policy barriers and future opportunities

This study discusses N management considerations in the agriculture food supply chain. Agriculture contributes most ammonia, nitrous oxide, nitrites, and nitrates to air and water, justifying the report's attention. Ammonia and nitrous oxides result from animal waste and nitrogen-based fertilisers released into the atmosphere. At the same time, nitrites and nitrates stem from excess fertiliser runoff and nitrogen compounds leaching into groundwater.

Other partner countries may use the developed analytical framework and methodology for similar analysis in agriculture and other N-relevant sectors.

SANH Overview

In a cooperative research programme on 'sustainable nitrogen management', the UKRI GCRF South Asian Nitrogen Hub (SANH) studies the impacts of reactive nitrogen pollution in eight countries: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. SANH brings together over 32 South Asian and UK institutions, including universities, institutes, NGOs, and SACEP, to support progress towards meeting the Sustainable Development Goals (SDGs) by addressing the nitrogen challenge and building a scientific evidence base. This research programme aims to support efficient nitrogen use, reduce nitrogen waste, and limit the adverse effects on people and the environment. Reducing nitrogen waste would benefit the air, water, land, seas, and human health while ensuring food security and offering huge economic savings (https://sanh.inms.international/).

1. Introduction

While the consequences of excessive carbon emissions have been extensively researched and documented, the risks associated with excessive reactive nitrogen (N_r) emissions have garnered comparatively little attention. Alarmingly, N has surpassed planetary bounds because of human activities, disrupting ecosystem functioning (Steffen et al., 2015; Sutton et al., 2019). The build-up of N_r compounds harms the ecosystem, leading to poor quality of air, soil, freshwater, and marine environment, climate change, eutrophication, and biodiversity loss (Galloway et al., 2003, 2008; Sutton et al., 2011a; Erisman et al., 2013; Abrol et al., 2017). However, the policy response to this environmental threat has been slow and disjointed. A global analysis collating 2,726 national and regional policies (here onwards referred to as the "global database"), including those of South Asia, revealed that worldwide, the N regulations on environmental sinks required coordination and integration and warned of severe repercussions for N pollution (Kanter et al., 2020a). This reiterated the global concern over the assessment of policy integration in environmental policy research to see how well policies have considered the dynamics and linkages within the system to prevent increasing environmental concerns (Mickwitz, 2003; Mickwitz & Kivimaa, 2007; Mcginnis & Ostrom, 2014; Gain et al., 2020).

Set against South Asia's critical role in the global nitrogen cycle, establishing the South Asia Nitrogen Hub (SANH) represents a pivotal step towards catalyzing transformative change and advancing a strategic approach to N management. Central to the research planned under the SANH from 2019 to 2024 was the analysis of the policy landscape and the exploration of barriers to collective action aimed at mitigating the regional effects of excessive N emissions. As one of the early milestones within the policy work package of the SANH, a thorough analysis of regional N-related policies in South Asia was conducted (Yang et al., 2022). Expanding the definition of policy beyond that used in the global database, the analysis included documents such as acts, laws, ordinances, plans, strategies, regulations, statutes, standards, rules, orders, codes, frameworks, and guidelines.

Agriculture emerged as the most prominent sector in global and regional datasets, accounting for 21% of all N policies in South Asia and 35% of the global nitrogen policy database. This was evidenced through earlier scientific research that clearly established the link between population growth and food production imperative, such as projecting a doubling of fertiliser inputs. In India, for instance, fertiliser consumption showed an increasing trend (Sutton et al., 2017), resulting in higher losses of N_r, indicated by the annual emissions of ammonia (Moring et al., 2021; EDGAR, 2016). However, a comprehensive analysis of policy effectiveness towards sustainable N_r management needs to be included. It is this gap that the current study tries to address through a thorough understanding of institutional procedures and stakeholder perspectives for a coherent strategy to address the N_r loss problem.

Stakeholders and stakeholder groups in agriculture policymaking are diverse, depending on different agriculture systems and political economy situations in different countries and regions. Amidst many systematic approaches, stakeholder analysis is found suitable for assessing policy contexts and evaluating implementation strategies from stakeholders' perspectives. Building upon the regional database developed by SANH (Yang et al., 2022), the goal of this study is to map global and national policy shifts pertaining to N management, identify major stakeholders, analyse their positions about N management-related policy decisions, and identify avenues for further engagement towards more effective N management regimes. For the country-level analysis, the study draws on India's agriculture sector. In this research, the decisions under consideration pertain to the agriculture food supply chain that impacts N management. The methods and tools

that are developed to analyse India's N management scenario can be easily replicated and adapted by other countries.

This report is organised as follows: Section two presents the rationale and objectives of stakeholder analysis; Section three discusses the study's analytical framework and methods; Section four presents the findings of the policy analysis and stakeholder analysis, respectively; and Section five delves into future actions and possible stakeholder engagement toward sustainable N management.

2. Rationale and Objectives of Stakeholder Analysis

Driven by the ever-increasing global food demand, agriculture remains a dominant source of N pollution in agriculture-dependent geographies. On one hand, N is an essential nutrient in agriculture and food production; on the other, its over-application poses a severe threat to the environment. On average, crops absorb only half of the N that is applied. On consumption, humans and animals also utilize only a fraction of it, leaving the rest to be stored in the soil temporarily or lost to the environment (Sutton et al., 2013). These N losses lead to serious environmental issues like eutrophication[1], air pollution, and biodiversity loss – to list just a few adverse outcomes. The growing use of fertilisers, on one hand, and increasing awareness of the social and environmental impacts of N pollution on the other, have left policymakers perplexed.

One of the reasons that could explain the policy gaps is that most of the policies have focused on farm-level decisions and behaviour change, thus targeting exclusively 'farmers' rather than the complete 'agriculture food supply chain'. Such restricted focus ignores a much larger group of influential actors in agricultural policy-making, adoption, and outcomes (Kanter et al., 2020). The agriculture food supply chain perspective offers scope for adopting a broad portfolio of policies addressing N pollution at various levels and scales. Thus, the current analysis expands the policy landscape by identifying stakeholders across the agriculture food supply chain and further engaging them in mapping the barriers and opportunities in current and future policy options for effective N management in Indian agriculture.

Stakeholder analysis enables systematic identification of stakeholders, their interests, roles, and powers, and how they are exercised towards various decisions of significance for N management. This study involved asking broad questions using the agriculture food supply chain as a framework for mapping stakeholders in N management policies, with reference to identified policies in four key decision areas: fertiliser reforms, crop residue management, organic practices, livestock, and feed waste management.

They are as follows:

- Who are the key stakeholders?
- What are their roles and interests vis-à-vis the policies/sub-sector decisions?
- What are their policy positions, and how do they influence decisions (or could potentially influence decisions) related to effective N management?

[1] An overabundance of nutrients—primarily nitrogen and phosphorus—in water starts eutrophication. Algae feed on the nutrients, growing, spreading, and turning the water green. Algae blooms can smell bad, block sunlight, and even release toxins in some cases. (Source: https://www.usgs.gov/mission-areas/water-resources/science/nutrients-and-eutrophication#:~:text=An%20overabundance%20of%20nutrients%E2%80%94primarily,release%20toxins%20in%20some%20cases.)

To address these questions, the stakeholder analysis framework, as illustrated by Reed et al. (2009) and the World Bank[2] has been referred to and adapted for India and its sectoral context.

Who are the stakeholders?
Stakeholders are actors (individuals or organisations) with an interest/stake in the decision/policy being discussed. These actors/organisations can either promote the policies or support them. However, they may also stall the process or resist the policies if it does not meet the interest of the stakeholders (Reed et al., 2009). These actors may include international actors (like donors, financial institutions, inter-governmental organisations or international non-governmental organisations), national political actors (like legislators and political parties), public service agencies and government actors (like ministries, departments, offices and officiating individuals), market actors (like commercial/private for-profit organisations, retailers/wholesalers, marketing agencies, mediators and channel actors), financial organisations (like public/private banks, particularly those that fund priority sectors), civil society actors/organisations (like NGOs, trade unions, labour unions, farmers unions, foundations, consumers, farmers) and so on. Example: The stakeholder dynamics within the agriculture sector are complex, with a variety of stakeholders involved in N management in different ways: • Community actors: farmers, consumers, farmer unions. • Market actors: input suppliers, financial institutions, traders, processing industries, manufacturers, retail organisations, etc. • Government actors: ministries/departments, extension agencies, research organisations, judiciary, financial institutions, international agencies etc.
Why stakeholder analysis? What gets analysed as part of stakeholder analysis?
Stakeholder analysis assesses the interests of key stakeholders and their influence over decisions/policies. In policy decisions, the analysis considers stakeholder traits like policy knowledge, policy-related interests, support or opposition to the policy, relationships/alliances with other stakeholders, and capacity to influence the policy process.

The specific research objectives for stakeholder analysis are:

1. To understand the existing N policy regime (international and national level policies and conventions, critical debates, and crucial decisions concerning N management)
2. To identify key policies and stakeholders with significant relevance to N management in Indian agriculture
3. To identify roles, interests, and influences of the identified stakeholders
4. To engage with key stakeholders on emerging policy barriers and future opportunities

In the next section, we discuss the analytical framework and methodology we adopted for stakeholder analysis.

[2] http://www1.worldbank.org/publicsector/anticorrupt/PoliticalEconomy/stakeholderanalysis.htm#matix

3. Analytical Framework and Methodology

3.1. Nitrogen Management in Agriculture Food Supply Chain: The Framework

Evidently most policy regimes aimed at managing N largely focus on changing farmers' behaviour (Kanter et al., 2020). However, not only is policy implementation at the farm level challenging but there are other contributing factors to N pollution in the agriculture food supply chain context. Actions from other actors like fertiliser production companies, consumer food losses, and N losses at water treatment plants also lead to anthropogenic contributions to N_r flow. Adapting the full-chain N use efficiency concept (Kanter et al., 2020), we developed a framework to identify key decision areas concerning N management policies along with stakeholders who affect and get affected by these policy decisions.

The agriculture food supply chain helps map the actors involved, from the production of nitrogenous fertilisers to agricultural production for final consumption and the resultant waste flows. The significant actors directly involved in the agriculture food supply chain are the fertiliser and seed manufacturers, farmers, processors, traders and retailers at the market level, consumers, and wastewater treatment companies. The actors indirectly involved in the chain via their influence over decision-making are state and non-state actors like policymakers, farm advisors and experts, extension services, financial organisations, research bodies, civil society organisations, and international regulatory bodies. Figure 1 represents the agriculture food supply chain from a N policy perspective.

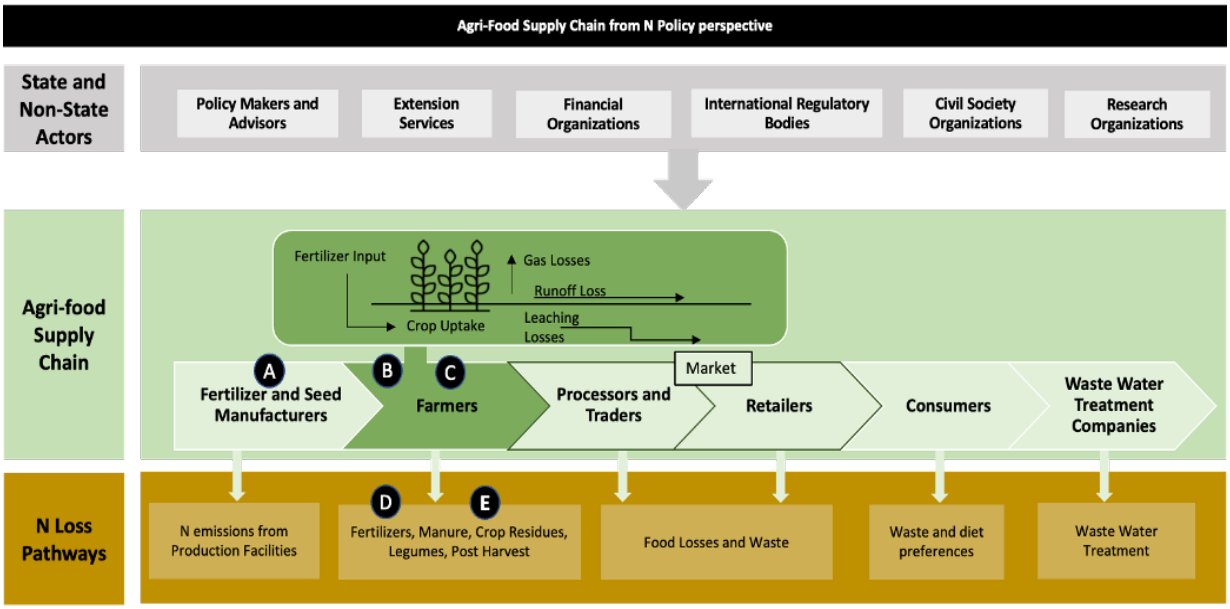


Figure 1: Agriculture Food Supply Chain from N Policy Perspective (Adapted from Kanter et al., 2020)

In Figure 1, the topmost level, depicted in grey, represents **state and non-state actors**. These actors include government agencies, international organisations, advocacy groups, and industry associations. While their decisions and actions do not directly contribute to N pollution, they significantly shape and influence the nitrogen policy process. They set the regulatory frameworks, standards, and guidelines that govern N management. The middle level, depicted in green, represents the **agriculture food supply chain**. This level focuses on the actors involved in agriculture and food production (such as farmers, agricultural extension services, and input suppliers) and the pathways through which N is used and managed at the farm level. It is at this

level that currently most policy decisions are concentrated, aiming to regulate and guide the use of nitrogen in agricultural practices. The bottom level, depicted in orange, represents the **N loss pathways**. This level illustrates the various stages of the supply chain where N can be lost to the environment, including losses from fields through leaching, runoff, and emissions. It highlights the environmental impact dimension of N use across the entire supply chain. Within this framework, the alphabet **A-E** represents distinct key policy decision areas (and clusters of policies) that are pertinent to N management in the Indian agriculture context:

- **A: Fertiliser Policies** – These policies are focused on the production, distribution, pricing, and use of chemical fertilisers.
- **B: Broad-Based Policies** – These encompass general agricultural and environmental policies that indirectly but substantially affect on N management.
- **C: Organic Farming Policies** – These policies promote organic farming practices that typically involve lower synthetic N inputs.
- **D: Livestock Policies** – These policies relate to managing livestock and their waste, which are significant sources of N emissions.
- **E: Crop Residue Management Policies** – These policies focus on managing agricultural residues, aiming to reduce burning practices that contribute to N emissions.

Thus, in India's context, too, the N management policy portfolio has primarily been farm-level focused.

3.2. Methodological Framework

This policy and stakeholder analysis has used qualitative, multi-stage and multi-dimensional approaches (Figure 2). As discussed in the analytical framework, we cover four major agricultural sector sub-sectors: fertiliser reforms, organic and sustainable practices, crop residue management, and livestock feed and waste management. The methodology is organised into three stages: policy identification, policy analysis, and stakeholder analysis. Data were collected through a desk review of key policies and literature (for mapping key debates, stakeholders, their interests, influences, and policy barriers) and empirical data collection (using expert interviews, focused group discussions and stakeholder interviews). We describe the methods briefly below.

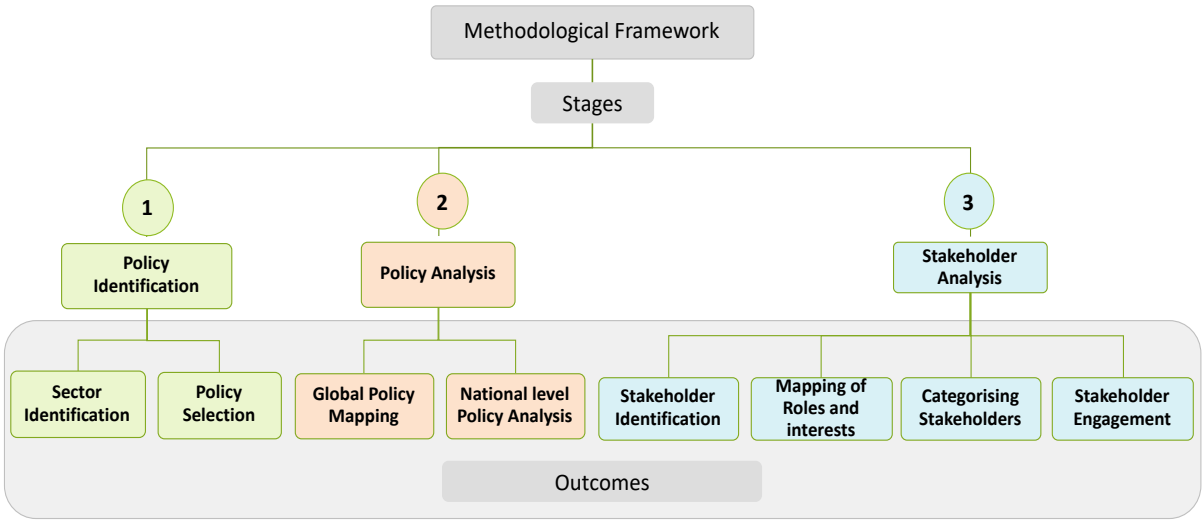


Figure 2: Flow Chart for Methodological Framework

Literature review overview

The literature review has been concurrent and iterative in this entire exercise. The main aim of the review was to map the global and national policy scenario, key stakeholders, their roles, and interests in N management. The following review criteria were employed, as presented in Figure 3.

REVIEW CRITERIA EMPLOYED

INCLUSION CRITERIA

- English Language, Electronic document
- Publication Period: From 1970-2022, aligned with the timeframe of the identified policies.
- Geographical context: Global and India
- Scholarly Database: Google Scholar
- Word Search: Nitrogen management in Agriculture, Nitrogen Use Efficiency in Agriculture, Fertilizer sector reforms in Indian Agriculture, Organic Farming Policies in India, Crop Residue Burning in India, National Livestock Policy India
- Document Type: International declarations, documents on market mechanisms and regulatory standards, review articles, journal papers, reports, case studies, articles, book chapters, guidelines and manuals, conference proceedings, thesis, working papers, web pages, and technical bulletins.
- Total Number of Documents Reviewed: 92

EXCLUSION CRITERIA

- Anything not falling in the four major sub-sectors identified i.e. fertilizer reforms, organic and sustainable practices, crop residue management, and livestock feed and waste management
- Documents that lacked policy or stakeholder context in the nitrogen management

Figure 3: Literature Review Criteria Employed

The review systematically gathered information and insights that could help identify which stakeholders (policymakers, policy influencers, state-level administrators, philanthropic organisations, and donors) were relatively more important and could impact N-related decisions/policies more.

Stage 1

Policy Identification and Selection

As a first step towards policy identification and analysis, we shortlisted relevant policies for effective N management in South Asia. Thus, 39 policies from 305 (as identified by the SANH database 2021) at the Indian level were shortlisted using the following criteria:

- Large Impact Scope – National Policies that greatly impact N management.
- Direct N Relevance – National policies that directly affect N management.

Positive, Mixed/Neutral Direction – Positive directional policies are those that (directly or indirectly) promote a reduction in N pollution. In contrast, mixed or neutral policies could have both positive and negative implications or if the policy is potentially neutral in its impacts.

The 39 policies identified in this process were from the following sectors: agriculture, waste, transport, land-use change, and food security.

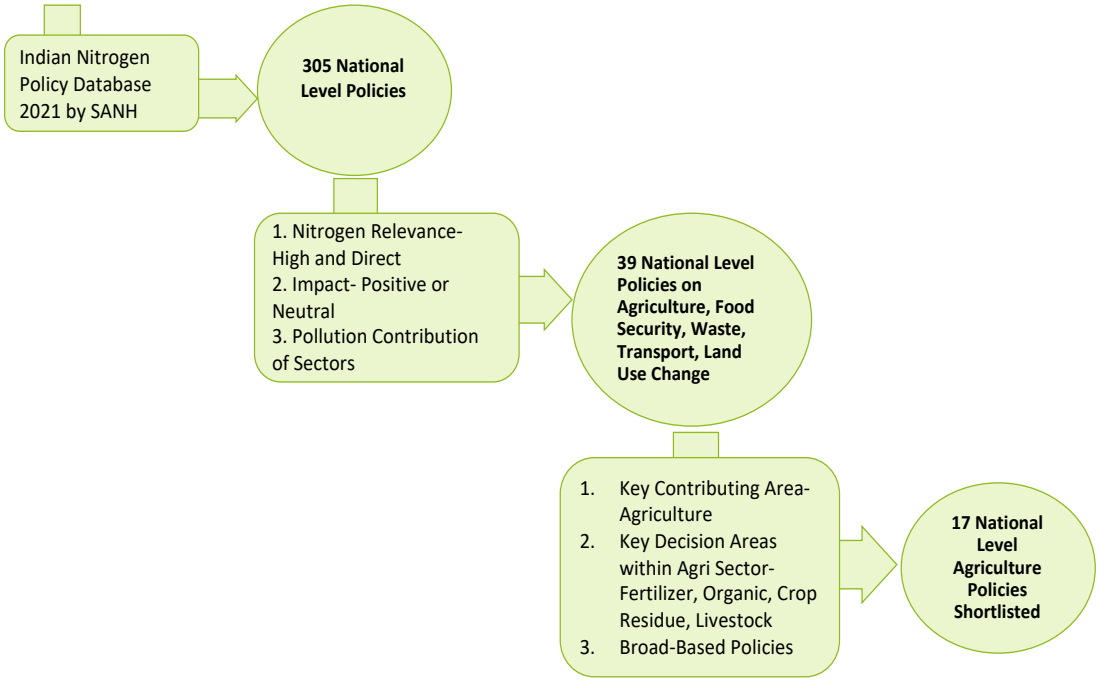


Figure 4: Policy Identification Criteria

As the primary contributing area of N pollution in South Asia, agriculture and allied sector policies were carefully studied, leading to the shortlisting of 17 key national-level policies at the Indian level for further analysis (Figure 4). The policy focus in each of the sub-sectors is elaborated in Table 1.

Table 1: Policy focuses for each sub-sector and broad-based policies

Sub-sector	Policy List	Policy Focus
Fertiliser reforms policies	The Fertiliser (Movement Control) Order 1973), Fertiliser (Control) Order 1985 (*Amended in 2013), Guidelines for Production and Use of Customised Fertilisers 2008, New Urea Policy 2015, Policy for encouraging production and availability of fortified and coated urea 2015	Regulating fertiliser production, sale, and usage; encouraging agriculture exports; maximising indigenous urea production; promoting site-specific nutrient management; maximising fertiliser use efficiency; promoting neem-coated urea production and adoption; and subsidy-related provisions.
Organic farming and sustainable practices	National Project on Organic Farming 2010, Paramparagat Krishi Vikas Yojana 2015	Promoting practices that sustain soil health and fertility, practices for integrated nutrient management, and evading the use of chemicals through manure management and natural N harvesting.
Crop-residue management policies	National Policy for Management of Crop Residue 2014	Curbing residual burning and promoting diversified use of crop residue.
Livestock feed and waste management policies	National Livestock Policy 2013	Managing farmyard manure and improving feed and waste management practices.
Broad-based policies	National Agricultural Policy 2000, National Policy for Farmers 2007, The Rashtriya Krishi Vikas Yogna or The National Agriculture Development Programme 2007, Bringing Green Revolution in	Nutrient management, agroforestry with cropland management, reclamation of degraded lands, mitigating air and water pollution, water availability and sustainable usage, innovations, and

	Eastern India 2010, National Mission for Sustainable Agriculture 2010, Pradhan Mantri Krishi Sinchai Yojana 2015, Soil Health Card Scheme 2015, Doubling Farmers Income Policy 2017	modern technology in agriculture operations.

Stage 2

Policy Analysis

Policy analysis was done at global and national scales, the former being important to understand the interlinkages between the international and the national N policy regimes and initiatives. The global level was necessary for setting the context. However, the research could not pursue a detailed international policy analysis or stakeholder engagement at this stage.

2a) Global Policy Mapping: The global analysis was conducted to analyse whether and to what extent the global policies have influenced or impacted the national policies. It further helped to develop an understanding of the current global N policy regime and the gradual shifts in international discourses.

2b) National Level Policy Analysis: Content analysis was carried out to understand how the selected agriculture sector policies (n=17) integrated N management concerns and how stakeholder dynamics have evolved to accommodate these demands or shifts. Content analysis, also known as textual analysis, aids in evaluating information contained within a document by understanding the language used in the text (Bryman, 2016). For instance, to identify whether policies are emphasising mechanisms to maximise NUE in crops, we used codes like "nitrogen use efficiency" OR "NUE" OR "fertiliser application" OR "fertiliser use" OR "nitrogen loss" OR "fertiliser requirement assessment" OR "nitrogen emissions" OR "site-specific nutrient management" in NVIVO software to identify relevant text. The agriculture food supply chain framework served as the foundation for developing a codebook (Annexure 1) that was referred to while coding the documents. The identified text was further examined for its context and decisions that were referred to for a clearer understanding of positions taken.

Stage 3

Stakeholder Analysis

Identifying and understanding stakeholders' positions in crucial decision areas within the agriculture and allied sectors is essential to highlight which actors (state and non-state actors, such as policymakers, farm advisors/experts and extension services, financial organisations, as well as research and civil society organisations and international regulatory bodies) are involved either directly or indirectly and/or are likely to have an impact on the outcome of the decision-making process. In addition to the literature review and content analysis already discussed, we carried out a) focus group discussions (FGD) and b) stakeholder interviews (discussed below in detail). The stakeholder analysis involved four steps: 1) Stakeholder Identification, 2) Mapping of Stakeholder Interest and Influence, 3) Categorizing Stakeholders based on their Interests and Influence, and 4) Stakeholder Engagement (See Figure 5).

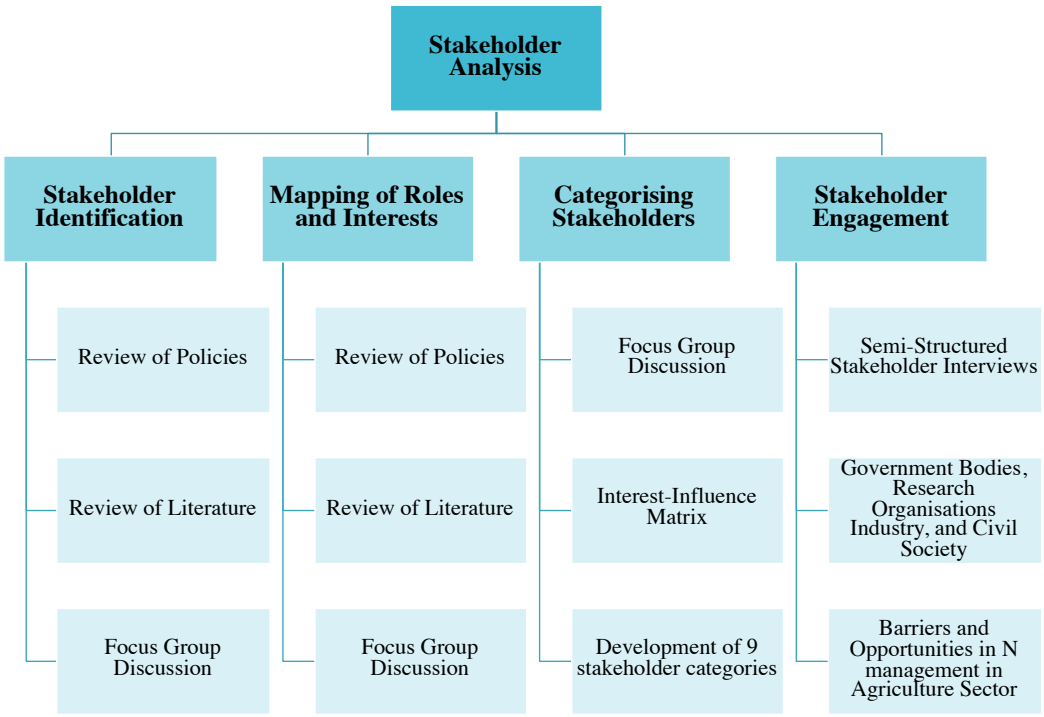


Figure 5: Stages of Stakeholder Analysis

1. Stakeholder Identification: Here, we asked the question: Who are the key stakeholders relative to the policy decisions? These actors were understood to have significant influence over the decisions (or are more impacted by the decisions) compared to other stakeholder groups. For this purpose, a list of stakeholders was prepared for each identified agriculture sub-sector using data from policies (n=17) and literature (n=92). This list was confirmed with the sector experts through FGDs to come up with a final list of key stakeholders. The stakeholders were categorised into government bodies (ministries and departments), industry and market actors, civil society (beneficiaries, donors, members, NGOs, other CSOs, media and public), research bodies (organisations /institutions) and international bodies. The outcome was a list of key stakeholders who are influencing and/or may influence and/or are impacted by a policy or policy decision.

2. Mapping of Stakeholder Interests and Influence: Interest indicates stakeholders' likely concerns and entailed benefits in the policy decisions, while influence indicates stakeholders' ability to resist or encourage change. This comes very close to the understanding of power because only those with the power to influence change can do so. The sources of power can result from position, property or resource, organisation, or even personality. Mapping interest and influence will indicate which actors will likely get involved directly or indirectly in decisions and policy reforms or who will be affected by them. Stakeholders can have conflicting or shared interests in pushing forward or obstructing a specific policy reform and, thus, may exercise power to influence change based on external pressures.

The Interest-Influence matrix is an interesting visual tool that enables mapping the interests and influence of all stakeholders with possible explanations of their positions. Likewise, we developed a matrix that depicted interest on the vertical axis (low to high) and influence on the horizontal axis (low on the left to high on the right). A 2 by 2 matrix helps position stakeholders' interests and influence at two levels, low and high (Eden & Ackermann, 1998). For a more nuanced depiction and understanding of these stakeholder positions, we prepared a 3 by 3 matrix (See Figure 6), where the levels of interest influence were further characterised into low, medium, and high (Yang et al., 2015). Using expert opinion, we mapped all identified stakeholders' relative interests and influence.

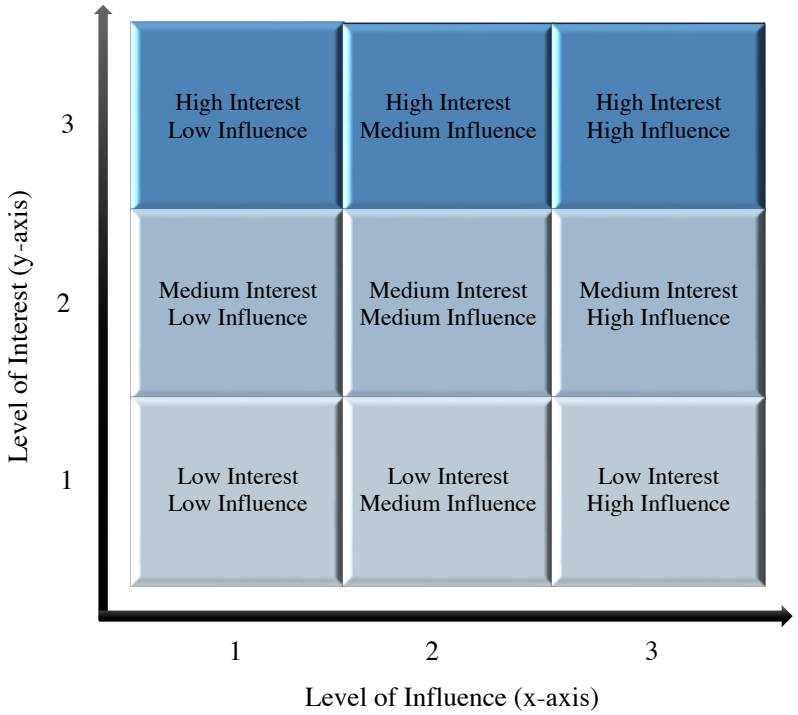


Figure 6: Interest & Influence Matrix
(Where, 1=low level, 2=medium level and 3= high level)

3. Stakeholder Categorisation: This is an analytical step where we attempted to group stakeholders into different categories based on their common or competing interests and influence. Stakeholder categorisation can be seen as a continuation of the power-interest analysis. Thus, it follows the same process as the interest-influence mapping, such as expert interviews and FGDs. Based on the positions mapped through the matrix, analytical categories were developed to assess the support and resistance of stakeholder/s to policy reform. To illustrate, **'Key players'** are those who hold the greatest stake and influence in the policy reform process and must be actively involved, while **'Subjects'** express interest in policy reforms and may get impacted by the decisions. However, their influence is insignificant (for instance, in this case, the Ministry of Agriculture and Farmer Welfare is regarded as a critical actor who steers the majority of policy decisions, while farmers with the highest level of interest but with the lowest degree of influence are categorised as subjects).

4. Stakeholder Engagement: Once stakeholders' roles, interests and influences were identified, semi-structured interviews were conducted with the key stakeholders to understand their position on N management and their views on the emerging policy issues. Stakeholders from the four categories – government bodies (n=2), industry and market actors (n=2), civil society (n=4), including organic farmers (n=8), and research organisations (n=3) – were interviewed (See Annexure 3 for details). The focus of the stakeholder interviews was on the current dynamics of the stakeholders in the existing policies in the context of N management, understanding the barriers and opportunities in carrying out effective N-management, and how the stakeholders can contribute to future scenarios.

Data Management and Analysis

For better data reliability and validity, different data sources were used for triangulation (government data sets and statistics, journal articles, reports from research institutions, and expert opinion/ validation). Qualitative data analysis techniques were utilised to systematise descriptive data obtained through interviews, focus group discussions, literature, policy documents and observations and later for analysing them. The approach seeks to recognise recurring themes and patterns in the underlying textual material. Two methods were particularly employed: content analysis and thematic analysis (see Bryman, 2016). Content analysis evaluates trends within a piece of content (words, phrases, images) or across several pieces or sources of data. With content analysis, text is categorised into codes, summarised into categories, and can be tabulated to calculate the frequency of specific concepts or variables. Content analysis blends quantitative and qualitative thinking. However, content analysis should follow an interpretive analysis to include all the qualitative nuances of the essential data. The thematic analysis examines thematic patterns in a data set, such as interview or focus group transcripts. Thematic analysis groups big data sets by similarities or themes that help in understanding the conceptual linkages within themes.

4. Findings

4.1. Mapping International N Policy Regime for effective N management

Following the United Nations Conference on the Human Environment (the Earth Summit) in 1972, which emphasised monitoring the environmental levels resulting from the emission of carbon dioxide, sulphur dioxide, oxidants, and nitrogen oxides (NO_x), the 1980s were characterised by several accords and conferences (see UNECE Air Convention, Stockholm Conference, Helsinki Sulphur Protocol of 1985, Sofia Protocol on NO_x, 1988, etc.) that were mainly concerned with industrial combustion sources, including those for power generation. As a result, the 1990s became a decade of international environmental accords, owing to breakthroughs with an increasing understanding of the issues with air pollution and depleting stratospheric ozone. Three significant agreements were adopted in 1992, during the Rio Earth Summit: the UN Framework Convention on Climate Change (UNFCCC), the UN Convention on Biological Diversity (CBD), and the UNECE Water Convention. Though each of these mentions N_2O as one of the greenhouse gases, the significance of N pollution is somewhat diluted. The impression that N is omnipresent and invisible is reinforced by expressing all greenhouse gas emissions as 'carbon equivalents'. Similarly, although the CBD includes N pollution among its incredibly varied list of Aichi Biodiversity Targets, N has failed to achieve the visibility required for substantial action.

Beyond climate and biodiversity, N_r is also intertwined in the water-food-energy-ecosystems nexus since much wasted N_r from atmospheric deposition and agriculture inputs enters watercourses, influencing water quality, ecology, and coastal fisheries (Sutton et al., 2020). Despite the UN N-related organisations and treaties since 1972, worldwide N waste has tripled. Fragmentation across several UN entities has constituted an unintentional impediment to coordinated management of the N cycle, as discrete N dimensions within each problem have frequently needed more weight to drive the change (Sutton et al., 2020).

Despite the general disregard for N pollution in international environmental discourse, the scientific community's participation in the UNECE Air Convention significantly impacted space for N-related discussions and actions at international forums that followed. The resultant 1999 multi-pollutant-multi-effect Gothenburg Protocol revealed the combined significance of nitrogen

oxide (NO_x) and ammonium nitrate (NH_3) emissions for particulate matter (PM) air pollution and ecological consequences (Bull et al., 2011). The existence of significant political obstacles to reducing agricultural ammonia emissions further highlighted the need for synergy throughout the N cycle to reinforce the argument for action. Because of this, the UNECE Air Convention established the Task Force on Reactive Nitrogen (TFRN), whose mission is to "develop a better understanding of the integrated, multi-pollutant nature of N_r that other bodies outside the Convention may use" (Sutton et al., 2014).

In addition, the International Nitrogen Initiative (INI), an international scientific collaboration, produced the European Nitrogen Assessment. Because of this assessment, national N budgets were included in the amended Gothenburg Protocol of 2012, guidelines on Ammonia (NH_3)mitigation were developed, and an evaluation was conducted of whether, and if so, how eating less meat and dairy products may decrease N pollution. Most recently, the UNECE guidance document on integrated mitigation of Ammonia, Di-nitrogen, Nitrogen Oxides, Nitrous Oxide, and Nitrate, as well as overall N losses, was adopted on December 18, 2020, during the first-ever e-session of the Air Convention's Executive Body. Everything from basic manure cover-ups to complicated nutrient recovery procedures is included in this list of ways to reduce N pollution. At the United Nations Commission on Sustainable Development in May 2009, the Global Programme for Action (GPA) established the Global Partnership on Nutrient Management (GPNM) to unify stakeholders' nutrient challenge efforts. The stakeholders included government, research, academia, private agricultural and fertiliser producer groups, regional and international intergovernmental organisations, and non-governmental organisations. Since then, GPNM has made it possible to scale up the N management strategy globally, resulting in articles that connect nutrients, climate, and the ozone layer, among other things. Following the GPNM efforts, collaboration among the International Nitrogen Institute, the United Nations Environment Programme (UNEP), and the Global Environment Facility (GEF) has built the International Nitrogen Management System (INMS) as a science-led method for policy support throughout the N cycle. These collaborations ultimately indicate that global N governance must go beyond the fragmentation that existed in the past. Further, taking concerted action on N has various advantages for the environment, human health, and economy.

Global progress on N has increased since GEF and UNEP founded INMS. In 2017, INMS and South Asia Co-operative Environment Programme (SACEP[3]) came together to create the first-ever UN Resolution on Sustainable Nitrogen Management, which the Fourth UN Environment Assembly accepted in March 2019. . The resolution gave UNEP the authority to cooperate with member nations to mobilise global N action at regional levels (Raghuram et al., 2021). The start of the UN Global Campaign on Sustainable Nitrogen Management in Colombo, Sri Lanka, in October 2019, advanced the process even further. The resulting Colombo Declaration agreed on halving N waste by 2030 as part of National Nitrogen Roadmaps while also approving the UNEP Road Map for Sustainable Nitrogen Management. Following this, the European Commission established a target to "reduce nutrient pollution by 50% by 2030" in its Farm to Fork and Biodiversity Strategies in May 2020 (Sutton et al., 2020).

[3] SACEP is an inter-governmental organisation promoting and supporting environmental protection, management and enhancement in South Asia. Established by the governments of South Asia, SACEP works in areas where regional cooperation and collective action benefit member countries and produce better outcomes for the region. Since its creation, it has implemented several projects and programmes in the areas of environmental education, environment legislation, biodiversity, air pollution, and the protection and management of the coastal environment (http://www.sacep.org/)

Furthermore, the CBD is currently exploring the adoption of a comparable aim in the future. In 2021, the International Nitrogen Initiative (INI) held its eighth global conference in Germany, culminating in the "Berlin Declaration on Sustainable Nitrogen Management for the Sustainable Development Goals (SDGs)." This pivotal document emphasised the critical role of comprehensive nitrogen management in the achievement of the SDGs. More recently, during the fifth session of the United Nations Environment Assembly (UNEA-5), member states of the United Nations were urged to formulate National Action Plans aimed at reducing nitrogen waste by the year 2030[4]. These developments highlight the growing international consensus on the importance of sustainable nitrogen management as a key factor in achieving global sustainability goals.

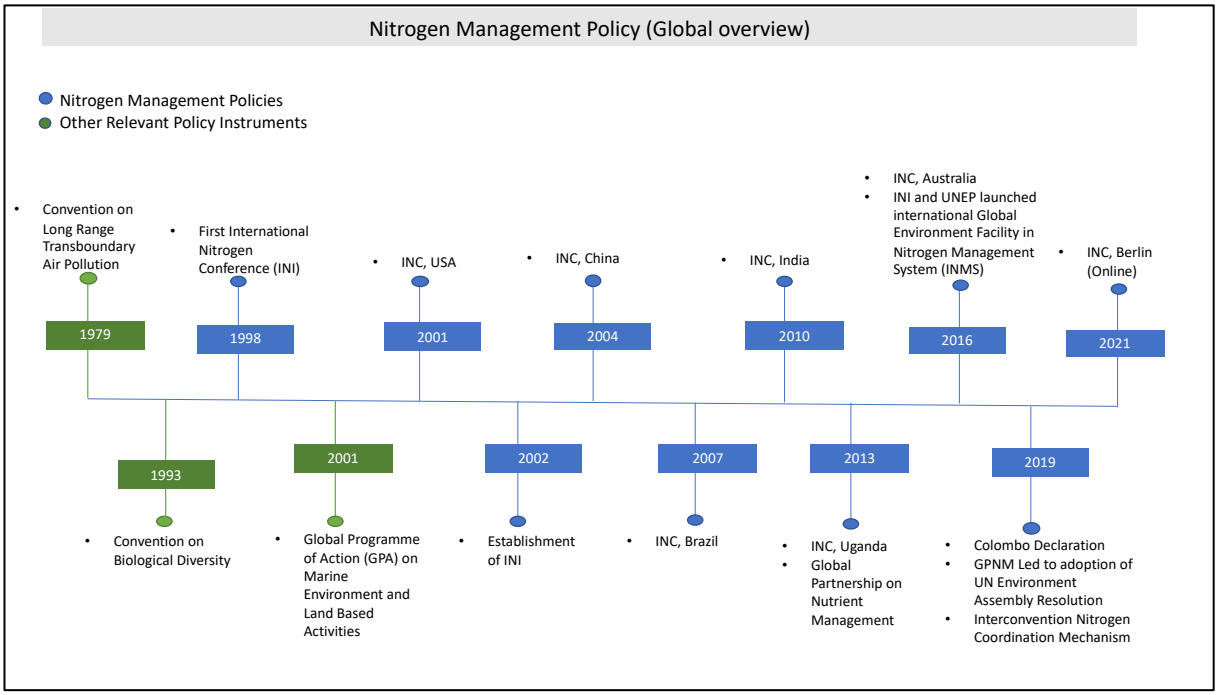


Figure 7: Timeline for International N Management Policy Regime (adapted from Raghuram et.al, 2021)

In conclusion, it appears that the problem of too much N has grown from a local hotspot problem to a global concern in the last five decades. Researchers have successfully been demonstrating that 'too little Nitrogen' is as much a problem as 'too much Nitrogen', thus emphasised promoting 'just enough Nitrogen' (Sutton et al., 2020). In fact, the recent developments in establishing the INMS also show hope for a global system of knowledge and resource sharing in combating N pollution.

International Influences on Indian Nitrogen Initiatives

This section explores the institutional developments shaping India's N management initiatives, emphasising the impact of international influences. The subsequent section will analyse the resulting policy developments within the Indian context.

The International Nitrogen Initiative (INI), founded in 2002, highlighted the scientific potential and increased interest in national and regional N assessments as the ideal means of coordinating intergovernmental efforts to advance N management agenda (Raghuram et al., 2020). Continuing its efforts, the INI hosts the International Nitrogen Conference (INC) every three years, where

[4] https://www.unep.org/resources/resolutions-treaties-and-decisions/UN-Environment-Assembly-5-2

participants from the global nitrogen community come together to share expertise and debate current nitrogen-related topics. So far, eight INCs have been organised in different regions, the latest being Germany's Federal Environment Agency (Umweltbundesamt – UBA) in 2021.

In the Indian context, the Society for Conservation of Nature (SCON), a volunteer organisation of scientists registered in New Delhi, pioneered the discussions around the need for an integrated approach to N research and policy in 2004 (Raghuram et al., 2021). They gathered a group of concerned Indian professionals from various backgrounds to examine the problem of N in agriculture, industry, and the environment. SCON held a series of nationwide consultations with the Indian National Academy of Agricultural Sciences (NAAS), the Indian Government's Department of Biotechnology (DBT), and the Indian National Science Academy (INSA) over the next few years, with active support from other related agencies such as the Ministry of Environment and Forests (MOEF) and the Council of Scientific and Industrial Research (CSIR).

As a result of the INSA workshop in 2006, these conversations resulted in the founding of the Indian Nitrogen Group (ING) under SCON. Soon after, ING contacted the INI, established in 2003, and convinced it to establish a South Asian Nitrogen Centre for improved regional and international cooperation. This suggestion was formalised in 2007 at Brazil's Fourth International Nitrogen Conference. ING-SCON played a crucial role in creating the South Asian Nitrogen Centre for INI and holding the 5th International Nitrogen Conference in New Delhi in 2010.

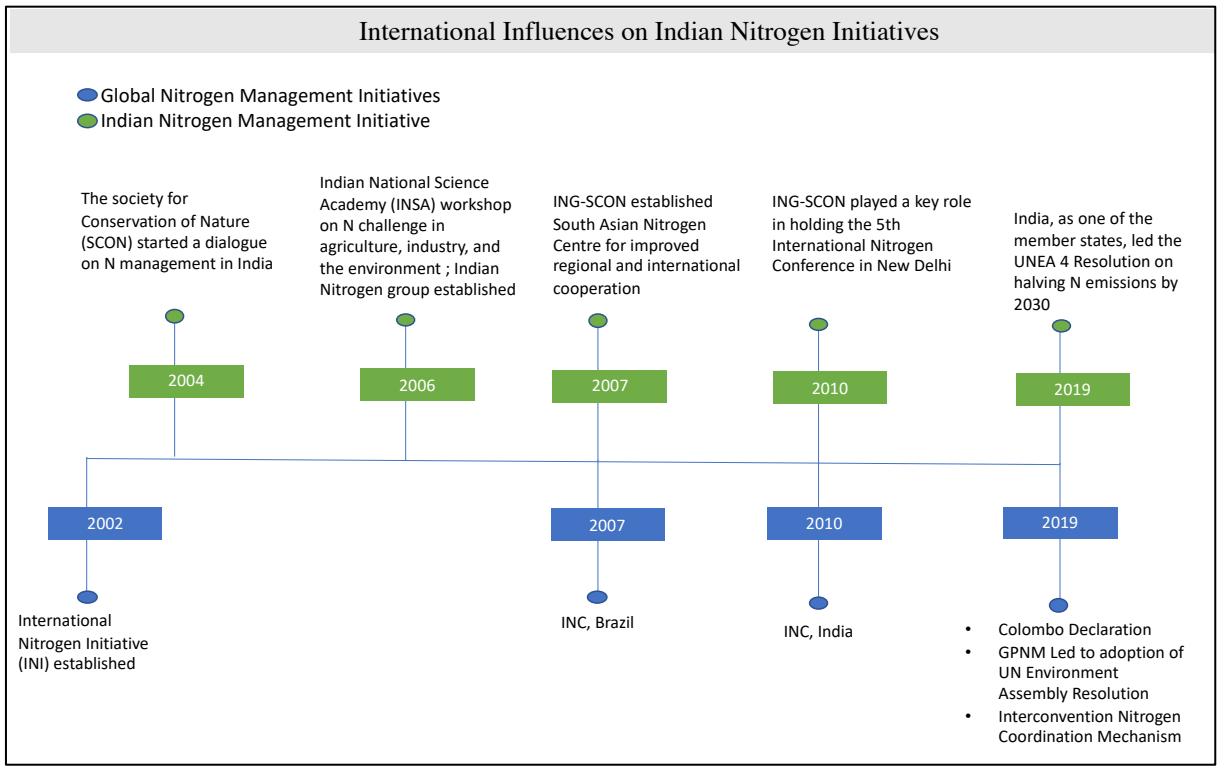


Figure 8: International Influences on Indian Nitrogen Initiatives

While the ING has laid the ground for an integrated approach to N research and policy in India, a coherent multi-stakeholder approach will ensure widespread adoption of N management solutions. In recent years, India has taken a leadership role in nitrogen management, primarily based on a directive from Prime Minister Narendra Modi. During his radio address, "Mann ki Baat," on November 27, 2017, he called for a 50% reduction in the country's chemical fertiliser consumption by 2022 (Sutton et al., 2020). While driven, such an aim has sparked global debate, implying the

policy and practice challenges in mitigating such complex environmental problems. In due course, India, one of the member states, led the UNEA 4 resolution in 2019 to halve N emissions by 2030.

4.2. Analysing national policies in the agriculture sector for effective N management through content analysis

Employing content analysis, the 17 shortlisted national policies (Annexure 2) were analysed using the developed codebook (Annexure 1) in the NVIVO software. In the software, pre-developed codes were used to extract relevant data. A subsequent round of open coding and thematic analysis was conducted to further refine and categorise the data into various themes and sub-themes. The findings were corroborated with the literature for drawing robust interpretations. We present these findings under four themes: development in fertiliser sector reforms and organic farming, crop residue management, livestock waste management, and changing stakeholder dynamics in the agriculture policies of India. The word clouds, the visual representation of the words that appear most frequently in the text in Figure 9, help visualise the policy focus pre- and post-2000. It is evident that early policies focused on fertilisers, and the central government was the key stakeholder in these policies, while the post-2000 policies show a shift towards a multi-stakeholder approach with a new focus on organic farming and impetus on research evidence and management. The following sections discuss these findings in detail.

(A) (B)

Figure 9: Word clouds developed in NVIVO to visualize the most used words in policy documents pre-2000 (A) and post-2000 (B) respectively.

Fertiliser Sector Reforms and Organic Farming Policies

With a policy impetus on tackling food shortage through enhanced agriculture production, the early 1970s saw a rise in N fertiliser uses in India. The Fertiliser (Movement Control Order) 1973 (FMCO) helped in channelling the distribution and the inter-state movement of fertilisers in India. It aided the sector's development, and significant gains in output continued throughout the 1980s and 1990s. In 1985, the Fertiliser (Control) Order (FCO) was implemented to ensure equitable distribution and availability of fertilisers to farmers. Its definition of fertilisers also included customised and bio- and organic fertilisers.

Along with increasing fertiliser production, the government desired to enhance food grain output and hence chose to maintain the current controlled-price system. To maintain the subsidy, the government initially raised the price of urea to represent the cost of manufacturing more accurately. Thus, urea prices increased over 38% between 1979/80 and 1980/81, then 17.5% in

1981/82. During the latter part of the 1980s, urea prices remained stable, driven by the government's intention to promote consumption and the rise of influential farmer movements across the country (Brass, 1995; Assadi, 1997; Varshney, 1998).

Subsidies on fertilisers surged from Rs 5.05 billion in 1981/82 to Rs 43.89 billion in 1990/91 because of increasing consumption and low retail prices (MoF, 1992, p. 105). They became a focal topic of debate on India's fiscal deficit and economic reforms since 1991. Thus, in the fertiliser policy reforms of 1992, which aimed to liberalise the markets, the DAP – Phosphorus (P) and Potassium (K) fertilisers – were decontrolled while Nitrogen (N) fertiliser – the urea – was still controlled by the government. This led to reduced consumption of P and K, while urea consumption increased manifold. Next year, the government restored P and K subsidies through policy changes, but it never altered the maximum retail price for urea.

In the 1990s to early 2000s, several policy efforts were made to reduce and rationalise fertiliser subsidies as part of an economic reform agenda for addressing fiscal, distributional, and environmental concerns. During the same period, attempts were also made to reform policies concerned with fertiliser production and distribution. Ultimately, in 2003, a New Pricing Scheme established India's urea production and distribution strategy. This scheme aimed to improve production efficiency while also encouraging urea manufacturing units to lower costs on their own and be competitive. However, this three-stage reform process barely altered the policy framework. Thus, the overall subsidy system led to an imbalanced nutrient usage, leading to detrimental effects on soil health and urea production (Gulati & Banerjee, 2015).

Raising concerns over the imbalance in fertiliser use has been the main reason for the shift in fertiliser policy towards the nutrient-based subsidy (NBS). However, even NBS Policy 2010 failed in controlling the imbalanced use of N, P and K nutrients due to lower price of urea than P and K fertilisers. The biggest issue is nutrient mining, in which crops extract considerably more nutrients from the soil than are applied as fertilisers (Gupta, 2007). Not only N, P, and K are being depleted in Indian soils, but also critical micronutrients such as sulphur, zinc, iron, and boron are in the same fate. The problem can directly be attributed to the excessive application of urea compared to other fertilisers (phosphorus and potassium-based), resulting in a massive imbalance of the N:P: K ratio, which has other costs, including environmental, health, and subsidy burden on the Government. While India's N:P: K fertiliser usage ratio has never been optimal, it has altered significantly during the last decade and a half (Table 1).

Table 2: Nitrogen: Phosphorus: Potassium (N:P:K) Ratios in the last 3 decades

Year	**N: P: K Ratio (in reference to acceptable 4:2:1 ratio)**
1991/92 (prior to the deregulation of phosphatic and potassic fertilisers)	5.9:2.4:1
1992/93 (post deregulation of phosphatic and potassic fertilisers)	9.5:3.2:1
2003/04	6.9:2.6:1
2010/11	4.7:2.3:1
2018/19	7.1:2.7:1

(Data Source: Advances in Management, 2021)

The latter part of the 2000s witnessed the promotion of organic farming practices in agriculture policies. National Policy for Farmers (NPF) 2007 mentioned that fertiliser pricing policies would be reviewed to promote the balanced use of fertilisers and encouraged the production and marketing of bio-fertilisers and organic manure. Organic farming is listed as one of the 'special categories' of farming in the NPF. The policy also stated that bio-fertilisers, bio-pesticides, and organic manure will be treated at par with chemical fertilisers for support and promotion. The work on neem-coated urea started in 2008 but was abandoned midway without any stated or identified reason. In the same decade, the National Mission for Sustainable Agriculture (NMSA), 2010, was implemented. The NMSA aims to make organic farming more sustainable, profitable, and climate-resilient. In collaboration with other missions, the plan also aims to build the ability of organic farmers and smallholders. In the same year, the National Project on Organic Farming (NPOF), which was launched as a pilot in 2004, was scaled up. It promotes the uptake of agricultural waste production units through capital investment subsidies provided by the National Bank for Agriculture and Rural Development (NABARD). It focuses on technical capacity building, information generation, technology development and dissemination, formulation of standards, input production and quality control facilitation, human resource development, and developing alternative low-cost certification systems for the Participatory Guarantee System (PGS). NPOF is one of India's most comprehensive documents on promoting organic farming. In 2013 and 2014, two additional agriculture sub-sector policies were implemented: the National Livestock Policy (NLP, 2013) and the National Policy for Crop Residue (NPCR, 2014). Both policies briefly addressed the in-situ management of farm-yard manure, with the NPCR 2014 further stipulating a provision to extend subsidies for transporting crop residue to fodder-deficient areas.

In 2015, the New Urea Policy (NUP) and Soil Health Card Scheme (SHCS) were implemented. The NUP was mainly formulated to revise the energy norms for all the urea units in India- making them more energy efficient and reducing the import dependency. Neem-coated urea was also included in the FCO. This was intended to reduce urea usage per plot since neem-coated urea improves the N use efficiency of crops, reduces N leaching, and checks the diversion of urea towards industrial uses[5]. However, the policy on neem-coated urea was unlikely to solve the fiscal challenge faced by the government and the agricultural industry. Currently, the NUP 2015 provides N fertiliser subsidies, which are being paid to the urea units. The urea units are eligible for the subsidy if they comply with new energy norms. In 2015, Paramparagat Krishi Vikas Yojana (PKVY) was launched as an extended component of Soil Health Management (SHM) of the NMSA. PKVY aims to support and promote organic farming, resulting in improved soil health.

Besides the fertiliser sector development, we also explored if policies emphasise mechanisms to maximise nitrogen use efficiency (NUE) in crops. Using content analysis, we found that only two policies mention N use efficiency in their text. First, the Guidelines for Production and Use of Customised Fertilisers (PUCF) introduced in 2008 in the Clause 20 B of FCO 1985–stressed the use of Customised Fertiliser to promote site-specific nutrient management to achieve maximum fertiliser use efficiency. But, the high cost of customised and organic fertilisers, coupled with the lack of organised markets for these alternative fertilisers, pose constraints on achieving sustainable agriculture. Second, the National Mission for Sustainable Agriculture 2010 (NMSA), emphasised the role of training and skill development programs in popularising practices for N use efficiency and improved management of N fertiliser through proper timing of application.

[5] https://pib.gov.in/newsite/printrelease.aspx?relid=159903#:~:text=Improvement%20in%20soil%20health%3B&text=Reduction%20in%20costs%20with%20respect%20to%20plant%20protection%20chemicals%3B&text=Reduction%20in%20pest%20and%20disease%20attack%3B&text=An%20increase%20in%20yield%20of,to%20an%20extent%20of%205.

Thus, major trends in fertiliser sector reforms vis-a-vis intended changes in farming practices can be categorised as follows (Figure 10):

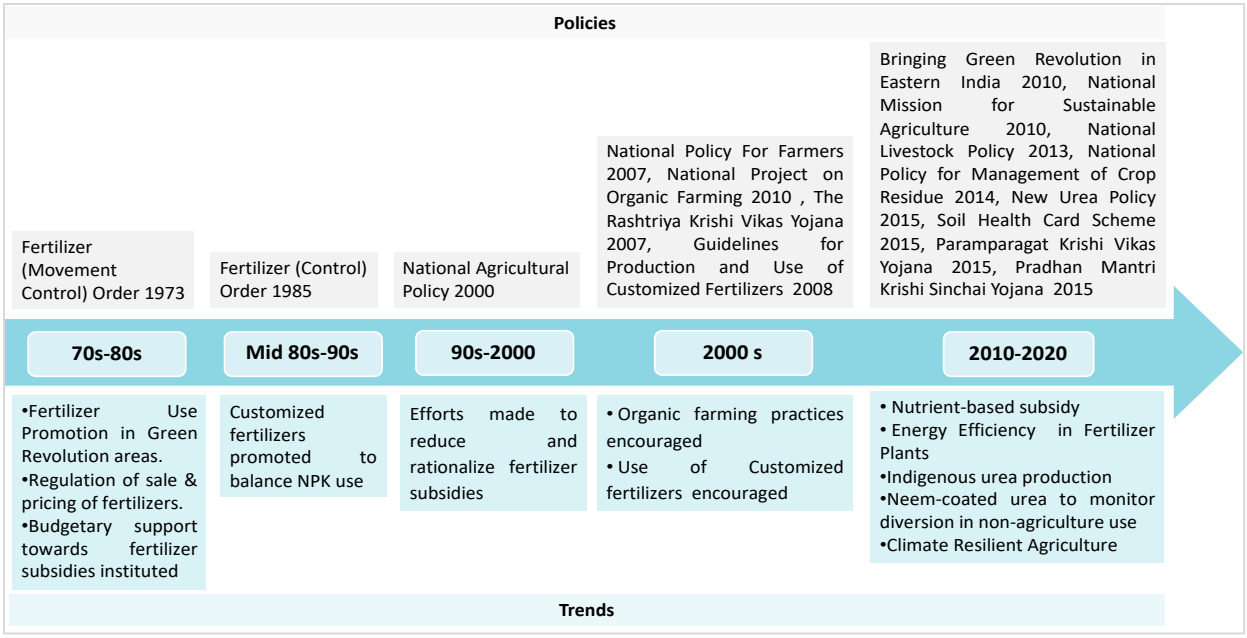


Figure 10: Key Policy Trends in Fertiliser Sector Reforms in India

Crop Residue Management

Content analysis revealed that only two recent policies have any provisions or guidelines for crop residue management: National Livestock Policy (NLP) 2013 and National Policy for Crop Residues (NPCR) 2014. The NLP 2013 recognised crop residue management as one of the concern areas for the first time in policy. It recognises crop residues as one of the major inputs for livestock feed and encourages enrichment and densification of crop residues by using existing and newly developed technologies. It highlights the role of government and private sector research organisations in technology support and innovations.

The NPCR 2014, aimed at curbing crop residue burning, stated that wheat, rice and sugarcane are prone to crop residue burning while these crops are 'preferred by farmers' as they provide 'good economic returns'. It recognises the challenges farmers face, like the high cost of removing the crop residue from the field and labour shortage, leading to large on-farm burning to clear land for the next crop. It also acknowledges that crop residue burning leads to high N losses. Crop residue contains 80% N, and policy suggests that if this N is retained in soil, it can lead to better soil health and nutrient content. The policy also mapped out a few intervention strategies like technological interventions (incentivising the purchase of happy seeder machine[6] by extending subsidy on such machinery), diversified use of crop residues, capacity building, and awareness generation, pilot studies on crop residue management, state-level laws to curb residue burning, financial mobilisation from various ministries, etc.

Livestock Waste Management

[6] The Happy Seeder is a tractor-operated device developed by the Punjab Agri University in conjunction with the Australian Centre for International Agri Research. Using the machine to chop and spread the paddy straw or stubble in the field allows farmers to directly plant wheat seeds while the organic matter from the straw or stubble enriches the soil.

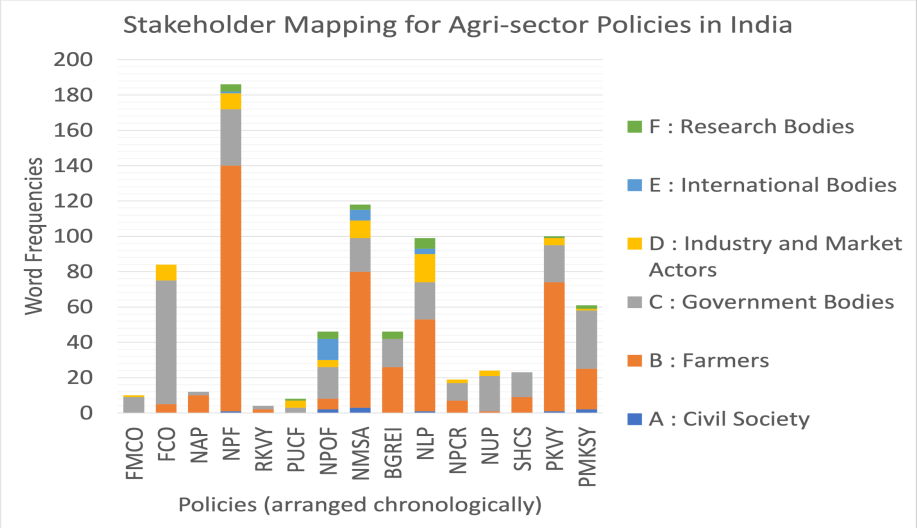
While policies like the National Livestock Policy (NLP) 2013 and Pradhan Mantri Krishi Sinchai Yojana (PMKSY) 2015 aim to raise awareness for better management of livestock waste and farmyard manure, they notably fall short in addressing the livestock sector's substantial contribution to nitrogen pollution. Similarly, although the National Mission for Sustainable Agriculture (NMSA) acknowledges that livestock waste leads to greenhouse gas emissions, it narrowly focuses on methane emissions, with reactive nitrogen emissions conspicuously absent from the policy documents. This is despite research findings such as those of Oenema et al. (2012) and Bouwman et al. (2013), which stress that N_r from livestock waste can lead to a variety of environmental problems, including air and water pollution, biodiversity loss, and soil acidification. The absence of specific attention to N_r emissions in these policy documents represents a critical gap, underscoring the urgent need for more comprehensive and integrated policy approaches that explicitly address the multifaceted challenges posed by nitrogen pollution from the livestock sector.

Stakeholder Dynamics in the Agriculture Sector Emerging from Policies

This section gives a snapshot of the evolving stakeholder dynamics derived from content analysis. The detailed roles and interests of key stakeholders are further discussed in the next section.

Out of the 17 selected policies analysed, 15 explicitly recognise the crucial role that agriculture sector stakeholders play during the policy execution and performance phases, highlighting the widespread acknowledgement of stakeholder engagement as a vital policy component. Figure 11 presents the content analysis results mapping the various stakeholder references in the selected policy documents. Government stakeholders (nodal ministries and departments) appear in all the policy documents. Farmers appear as key stakeholders in farmer-welfare-oriented policies like NPF 2007, NMSA 2010, and PMKSY 2015. Besides, it is worth noting that international bodies and research organisations are rarely mentioned in the policies.

Since the mid-1980s, the agriculture sector policies incorporated the idea of participatory multi-stakeholder engagement (Table 2). In earlier policies, central and state government came to be represented as the key and the only stakeholder – exercising power and regulating the distribution, pricing, and quality control (in the FCO, 1985), authorising exports from one state to another (in FMCO, 1973), and granting permission for fertiliser manufacture and sale (in FCO, 1985). Research institutes like agricultural universities and central laboratories gained significance later for soil testing and fertiliser sample testing (Guidelines for FCO 1995).



FMCO: The Fertilizer (Movement Control Order 1973)
FCO: Fertilizer (Control) Order 1985 (*Amended in 2013)
NAP: National Agricultural Policy 2000
NPF: National Policy For Farmers 2007
RKVY: The Rashtriya Krishi Vikas Yojana or The National Agriculture Development Programme 2007
PUCF: Guidelines for Production and Use of Customized Fertilizers 2008
BGREI: Bringing Green Revolution in Eastern India 2010
NPOF: National Project on Organic Farming 2010
NMSA: National Mission for Sustainable Agriculture 2010
NLP: National Livestock Policy 2013
NPCR: National Policy for Management of Crop Residue 2014
NUP: New Urea Policy 2015
SHCS: Soil Health Card Scheme 2015
PKVY: Paramparagat Krishi Vikas Yojana 2015
PMKSY: Pradhan Mantri Krishi Sinchai Yojana 2015

Figure 11: Frequency of references to stakeholders in agricultural sector policies in India

National Agriculture Policy 2000 highlighted small and marginal farmers as one of the stakeholders for the first time in any agriculture sector policy. NPF, 2007, was the first agriculture sector policy to emphasise the importance of multi-stakeholder engagements (National Agricultural Research System i.e. NARS for social inclusion in access to new technologies, Panchayat functionaries to guide farmers on appropriate land use, Krishi Vigyan Kendras (KVKs) to link farmers to technological up-gradation, Agricultural Produce Market Committees (APMCs) for market development, farmers and Self-Help Groups (SHGs) as stakeholders in farmer companies). Recognising organic farming as an emerging field in India, the National Project on Organic Farming, 2010, highlighted the necessity of liaising with international bodies and increasing stakeholders' international exposure to foster growth and standards in this sector. PKVY 2015 mandates the involvement of producers and consumers in the organic certification process for building trust. While multi-stakeholder engagement and functional role definition seemed to be positive developments, the engagement appeared biased towards the execution and adoption side rather than fostering innovative policy engagement. Notably, the authority to initiate and shape innovative policy engagements still seemed to rest predominantly with central government authorities.

The NPCR 2014 underscores the importance of a collaborative approach among diverse stakeholder groups (including Central and State Government, Research Bodies and Extension Services, Civil Society-Farmers and Media) to tackle the issue of crop residue burning. Recognising farmers as pivotal stakeholders, the policy emphasises capacity-building in crop residue management, advocating for educational programs and schemes tailored to their needs. This aligns with the literature findings suggesting that farmer education and capacity-building are

essential components in reducing residue burning (Sharma et al., 2019). Furthermore, the policy also highlights the necessity of enhancing the expertise of Extension Services through focused training.

Table 3: Stakeholders as Identified from the Content Analysis of National Policies

Policy Document	Year	Key Stakeholder Mentioned in the Policy
FMCO	1973	Central Government, Industry, Research Bodies
FCO	1985	Central Government, State Government
NAP	2000	Central Government, Farmers
NPF	2007	Farmers, Central Government, State Government, Industry and Market Actors, Research Bodies, Panchayat level functionaries
RKVY	2007	Central Government, State Government, Farmers
PUCF	2008	Central Government, State Government
BGREI	2010	Central Government, Research Bodies
NPOF	2010	Central Government, State Government, Farmers, Research Bodies, Extension Agencies, International Bodies, CSOs
NMSA	2010	Central Government, State Government, Farmers, Industry and Market Actors, Research Bodies, Research Bodies, International Bodies, CSOs
NLP	2013	Central Government, Farmers, Industry and Market Actors, Research Bodies, CSOs and Cooperatives
NPCR	2014	Central and State Government, Research Bodies and Extension Services, Farmers
NUP	2015	Central Government, Fertiliser Industry
SHCS	2015	State Government, Extension Services
PKVY	2015	Central and State Government, Producers and Consumers
PMKSY	2015	Central Government, State Government, District level line departments, farmers, micro-irrigation industry, CSOs

4.3. Stakeholders' Roles and Interests

Since the initial focus of agricultural policies was on food security, the scope of policymaking saw restricted engagement, including only central ministries and a couple of others, like research bodies, that provided technological wherewithal to implement large-scale programmes. Only later did environmental concerns start being flagged (as seen in the policy mapping), and more stakeholders got involved. The agriculture value chain saw more diversification, and the engagement and alliance of actors was needed to understand the policy shifts. The following section maps the developments of these sectors' (fertiliser, organic, crop residue and livestock) alongside the key stakeholders involved. These findings emerged from the literature review and policy analysis process that the experts in focus group discussions further validated.

4.3.1 Fertiliser Sector

Following the post-independence food shortage experiences in India, productivity enhancement became the key concern for central ministries and thus the impetus on primary nutrient (N-P-K) based fertilisers. In pursuit of this, the central ministries, notably the Ministry of Agriculture and Farmer Welfare (MoAFW), Ministry of Chemical and Fertilisers (MoCF) and state agricultural departments enforced policy measures (viz. the Fertiliser Control Order 1957 and Fertiliser (Movement) Control Order 1973) that regulated the sale, pricing, and quality of the fertilisers throughout the country. Manufacturing firms (such as National Fertilisers Limited, Rashtriya Chemicals & Fertilisers Limited) and cooperatives (such as Indian Farmers Fertiliser Cooperative Limited, i.e. IFFCO, and Krishak Bharati Cooperative Limited i.e. KRIBHCO) facilitated the overall fertiliser production capacities. In addition, the organised and commercialised handling of fertilisers—for example, by the State Agro-Industries Development Corporations and Commodity Federations—involved numerous private intermediaries and cooperatives that aided fertiliser accessibility. Oil sector companies also impacted fertiliser production by regulating gas prices during this period. Further, on the guidance of a committee constituted by the Reserve Bank of India (RBI), the National Bank for Agriculture and Rural Development (NABARD) and regional rural banks were instituted by the central government to augment funding structures and facilitate agricultural research extension and credit services for farmers. The literature points out that even when farmers attempted to reduce the imbalance in the N-P-K ratio, external shocks and policy distortions made it difficult for them to continue their efforts (Fertiliser Use and Imbalance in India, 2015).

Until 2000, the Department of Agriculture and Cooperation (DoAC) under MoAFW did not prioritise the ramifications and interdependence of fertiliser subsidies and nutrient imbalances, prompting intervention by the Department of Fertilisers (DoF). After that, in 2003, the 'New Pricing Scheme' was put in place, replacing the previous 'Retention Price Scheme'[7], as per the recommendation made by the Expenditure Reforms Commission. Over time, concerns about unsustainable agriculture practices grew among researchers and scientists, resulting in nationwide consultations (such as the 2005 NAAS Conference) for enabling N management and NUE. These consultations emphasised the need to foster collaborations between the scientific community and the government to yield tangible results for India's agricultural sector. In collaborative efforts to improve agricultural technology, quality fertiliser and its usage efficiency, various stakeholders, including the Ministry of Environment, Forests and Climate Change (MoEFCC), the Council of Scientific and Industrial Research (CSIR), the Department of Biotechnology, and the Indian National Science Academy played an active role. The central ministry-MoCF implemented conscious efforts to decrease subsidy burdens and enhance productivity (for instance, adopting a nutrient-based subsidy scheme[8]) in collaboration with diverse stakeholders at various levels, including- State agriculture departments, federal agencies (like DoF, DoAC, and the Department of Academic Research and Education), governmental bodies (National Centres of Organic Farming i.e. NCOF, and Central Fertiliser Quality Control and Training Institute i.e. CFQCTI), as well as extension agencies like KVKs.

[7] With rising concerns over self-sufficiency in urea production, the Fertilizer Prices Committee (under the Chairmanship of S. S. Marathe) recommended the Retention Pricing Scheme (RPS) in 1977, approved by the Cabinet Committee on Economic Affairs to ensure a fair return on investment besides farmer affordability (Gulati et al., 2015).

[8] However, leaving urea out of the policy's scheme's ambit proved to be a mistake on the ministry's part, since it led to urea misuse and further disturbed the N-P-K ratio. The Planning Commission acknowledged this in its twelfth plan document, which states (on page 14 of volume 2) that "NBS roll-out was significantly flawed since urea was kept out of its ambit" (Gulati et al., 2015).

The promotion of sustainable agricultural production was facilitated by the implementation of various policy initiatives in 2015, such as the New Urea Policy, Neem Coated Urea, and Soil Health Card Scheme, which received technical support from the National Agricultural Research System (ICAR, SAUs, and IARI), with emphasis on addressing sustainability issues and fertiliser policy gaps. Whereas the Niti Aayog facilitated the new urea policy for reducing subsidies and enhancing energy standards, the Ministry of Petroleum and Natural Gas (MoPNG) enforced revised standards for energy-efficient urea production. MoCF made it mandatory for domestic urea manufacturers to produce 100% Neem Coated Urea. At the same time, MoAFW introduced a soil health card programme, aided by extension agencies (such as KVKs), to promote balanced nutrient use. The implementation and administration of the scheme, however, were met with scepticism by farmers interviewed. Promoting bio-stimulants and alternative fertilisers, including nano-fertilisers, has recently increased interest by MoAFW and DoF. The adoption spectrum of these fertilisers has also been extensively researched by organisations such as IIFCO.

In conclusion, while the central government still dominates the fertiliser sector, state governments[9] are equally empowered to make and enforce policy through extension agencies. In addition, there are other influential players, such as the Cabinet Committee on Economic Affairs (CCEA), that drive fertiliser policy reforms. Though renowned for their scientific contributions, research institutes have had limited[10] participation in decision-making compared to other nations. Meanwhile, fertiliser companies and market players (including input dealers, exporters, etc.) still prioritise maximising profits and expanding production capacities. While some farmer-centric CSOs (such as the Centre for Sustainable Agriculture) have advocated for sustainable agricultural practices, their efforts to promote fertiliser usage efficiency during the reform era have been somewhat restricted.

Table 4: Identified Fertiliser Sector Stakeholders and their Interest

Government Stakeholders	Interest
Ministry of Agriculture and Farmers Welfare (MoAFW)	Agricultural income, Fertiliser suitability assessment and recommendation for agro-climate regions, price related provision
Ministry of Chemicals and Fertilisers (MoCF)	Maximising domestic fertiliser availability; balancing imports and domestic pricing, affordability, and timely supply; energy efficiency in N, P production, fertiliser subsidies, Alternative Fertiliser
Ministry of Petroleum and Natural Gas (MoPNG)	Energy efficiency and energy sustainability in fertiliser production
Ministry of Environment, Forests and Climate Change (MoEFCC)	Environment sustainability and policy
Ministry of Consumer Affairs, Food and Public Distribution (MoCAFPD)	Procurement and distribution
Ministry of Finance (MoF)	Macro-economic policy impact assessment

[9] The Focus Group Discussion pointed at 'Agriculture' being the state subject as per Entry 14, while some agriculture-related items have been included in the Union List and the Concurrent List; thus, Centre and State work in tandem in policy design and implementation.

[10] There may be instances where this is not true (exceptions), but largely, they are not involved (which also gets confirmed later in the FGDs).

Cabinet Committee on Economic Affairs (CCEA)	Political and administrative coordination
Niti Aayog/Planning Commission	Sustainable agriculture, fertiliser use efficiency
Supreme Court (SC)	Environment sustainability, constitutional / legislative compliance, Influence policies through green bench
Central Pollution Control Board (CPCB)	Pollution control
Agriculture Development and Rural transformation Centre (ADRTC)	Pro-farmer Policy reform, Agriculture Diversification
National Bank for Agriculture and Rural Development (NABARD)	Sustainable and equitable agriculture, promotion of govt policies through credit allocation
Research Bodies/Organisation	**Interest**
National Agricultural Research System (NARS)- ICAR, IARI, SAU, KVK	Sustainable agriculture promotion through R&D, capacity building
Central Fertiliser Quality Control and Training Institute (CFQCTI)	Fertiliser efficiency, Quality Control
National Centres of Organic Farming (NCOF)	Organic & sustainable agriculture practice
Industry (Public/Private)	**Interest**
Fertiliser Industries (Madras Fertilisers Ltd., Rashtriya Chemicals & Fertilisers Ltd, National Fertiliser Ltd., KRIBHCO, IFFCO)	Profit
Market Actors (Input Dealer, Exporters)	Profit
Fertiliser Association of India (FAI)	Profit/Energy efficient fertiliser promotion
Civil Society/Media	Interest
Farmers/Farmers Association	Increased productivity and Income
Federation of Indian Chambers of Commerce and Industries (FICCI)	Sustainable business; incentivising emission reduction
Non-Government Organisations	Environmental sustainability through regular monitoring, assessments, reporting
International Bodies	**Interest**
Food and Agriculture Organisation (FAO), India	Environment sustainability; fertiliser use efficiency; food security

(Data source: Policy analysis, Literature Review and expert FGDs)

4.3.2 Organic & Sustainable Practices

The renewed interest in organic agriculture in India was driven by declining agricultural productivity due to excessive use of chemical inputs and soil fertility reduction, which prompted several stakeholders to act, including various ministries, universities, research centres, and NGOs.

The International Federation of Organic Agriculture Movements[11] (IFOAM) played a critical role in inspiring and assisting agricultural scientists and CSOs in the 1980s and 1990s to spearhead the organic campaign[12]. Following this, it drew considerable attention from policy-makers, leading to policy reforms by the Ministry of Agriculture and Farmers Welfare (MoAFW) and the Department of Agriculture and Cooperation (DoAC) backed by third-party certification. By the year 2000, efforts were focused on the production and marketing of organic agriculture through diverse action groups. A task force (under the chairmanship of Shri Kunwar Ji Bhai Yadav) set up by the MoAFW and DoAC in the year 2000 was recommended (these included setting up biogas plants, developing organic market structures, incentives for farmers, recognising certification agencies) an action plan for the advancement of organic agriculture. After that, the organic farming concept was propagated in the plans of the MoAFW, DoAC, and Planning Commission, including the 10th National Action Plan, and a pilot project on organic farming was initiated. The concerted efforts of the Ministry of Commerce (MoC) and the Agricultural and Processed Food Products Export Development Authority (APEDA) established the National Programme for Organic Production in 2001, which played a significant role in promoting organic agriculture. Moreover, the growing prominence of the organic sector stimulated the active involvement of corporate entities and NGOs, who were influential in mobilising new forces and alliances (viz. Indian Organic Certification Agency, INDOCERT 2001).

Despite these attempts, the efforts to promote organic farming were inadequate in soil health assessment, affordable inputs, and quality control measures. In pursuance of this, the MoAFW initiated a National Project on Organic Farming in 2004, facilitated by the valuable inputs from the Planning Commission and executed through the National Centre of Organic Farming (NCOF). The NCOF provided institutional backing to urge farmers to participate in organic crop production by offering essential information and material inputs like biofertilisers. Collaborative efforts from the Food and Agriculture Organisation, India (FAO) were extended through various technical programs. Further, through its certification processes, the APEDA strictly regulated the authentication of organic produce. The establishment of organic input production units was supported by financial assistance through a credit-linked and back-ended subsidy from the National Bank for Agriculture and Rural Development (NABARD) and the National Cooperative Development Council (NCDC).

However, concerted efforts to promote organic farming began a decade later under the National Mission of Sustainable Agriculture (Khurana & Kumar, 2020). NARS institutes (like the Indian Council of Agricultural Research-ICAR and the Indian Institute of Farming Systems Research-IARI) were crucial in fostering technological innovation in the organic industry. The promotion of organic and bio-fertilisers has been the pursuit of the MoAFW and DoAC, with close collaboration from the Department of Fertilisers (DoF) to ensure policy alignment. The involvement of state governments was instrumental in creating agriculture policies tailored to each state's unique needs, executed with the help of extension agencies (such as the National Institute of Agricultural Extension Management i.e., MANAGE). The media played an essential role in bringing to light the issues surrounding organic fertiliser quality, the credibility of state and federal testing labs, ineffective administration, and farmers' concerns (Down To Earth 2018). The market players (input suppliers, exporters) were driven solely by profit motives. The active participation

[11] It is an umbrella organisation for organic agriculture that developed international basic standards for organic agriculture. It established the IFOAM accreditation programme (1992) to accommodate certifying agencies and set up an international organic accreditation service (2001).

[12] These were the first-ever NGO conferences held in Wardha in 1984 by the Association for the Propagation of Indigenous Genetic Resources, Bordi Conference in Maharashtra, serving as the epicentre of India's organic agricultural movement, and United Planters' Association of South India (UPASI) conference in 1993 and 1995.

of civil society, including farmers, media, and NGOs, in the organic movement in India was primarily limited to the implementation phase rather than decision-making. In 2006, through the inclusion of biofertilisers, organic fertilisers under the regulatory jurisdiction of the Fertiliser Control Order 1985, and organic farming under the PKVY program, the MoAFW played a crucial role in promoting chemical-free farming systems.

There have been recent deliberations at Niti Aayog (earlier Planning Commission) pertaining to the advancement of Zero Budget Natural Farming [13] throughout India. Various research institutions have evaluated the efficacy of ZBNF in comparison to chemical-based farming. Moreover, for decentralised quality-assurance systems, the MoAWF has initiated a Participatory Guarantee System of Certification for India (PGS-India)[14] with the active participation of civil society stakeholders. The growing consciousness of the harmful effects of chemical fertilisers has led consumer preferences to shift towards organic food choices. Nonetheless, the elevated cost of organic products has limited the market to high-end consumers.

Table 5: Identified Organic Sector Stakeholders and their Interest

Government Stakeholders	**Interest**
Ministry of Agriculture and Farmers Welfare (MoAFW)	Agricultural income, Fertiliser recommendation for various agro-climatic regions, Sustained soil health
Ministry of Chemicals and Fertilisers (MoCF)	Promotion of organic fertilisers, Balanced fertiliser use
Ministry of Small and Medium Enterprise (MSME)	Organic farming related Enterprise development and support
Niti Aayog/Planning Commission	Promotion of organic practices
Agricultural & Processed Food Products Export Development Authority (APEDA)	Export promotion and development
Export Inspection Council of India (EIC)	Quality and safety of products
National Institute of Agricultural Extension Management (MANAGE)	Extension Management, Action Research
National Bank for Agriculture and Rural Development (NABARD) & National Cooperative Development Council (NCDC)	Sustainable and equitable agriculture, promotion of government policies through credit allocation
Research Bodies/Organisation	**Interest**
National Centres of Organic Farming (NCOF)	Promotion of organic practices
NARS (ICAR-IARI, SAU, KVK) and Public Funded Research Organisations (PFOs)	Conservation Agriculture, Policy reforms through research and, Technological Innovations, Technology transfer
Food Safety and Standards Authority of India (FSSAI)	Ensures quality and reliability of organic products, farmer welfare
Industry (Public/Private)	**Interest**
Market Actors (Wholesalers/Processors/Traders/Exporters)	Profit
Certification Agencies	Regulation and sale of genuine organic produce and products

[13] Press Information Bureau Government of India. https://pib.gov.in/FactsheetDetails.aspx?Id=148598

[14] PGS-India (2015-16) is a decentralised organic farming certification system. As per the International Federation of Organic Agriculture Movements (IFOAM), PGSs are locally focused quality-assurance systems.

Fertiliser industries (M/s Spiral Services, J.K Fertilisers, Agriland Biotech, Coromandel, IFFCO)	Profit, Promotion of organic produce
Civil Society/Media	**Interest**
Farmers/Farmers Association	Soil health; crop yield; income/returns
Agriculture-oriented Non-Govt. Organisations	Promotion of organic practices
Consumers	Quality of produce and health; availability and affordability
International Bodies	**Interest**
Food and Agriculture Organisation (FAO), India	Integrated Natural Resources management; food security
International Trade Centre (ITC)	Sustainable Trading and growth

(Data source: Policy analysis, Literature Review and expert FGDs)

4.3.3. Crop Residue & Management Sector

The attention to crop residue burning gained momentum post-1980s when mechanised harvesting resulted in substantial stubble or crop residue in the field (Kaushal, 2020). A substantive shift in the articulation of the issue was seen in 1998 when, with the increasing concern of transboundary air pollution in the Delhi-NCR region, the Supreme Court of India mandated the Environment Pollution (Prevention and Control) Authority under the MoEFCC (then MoEF) to monitor and take actions against crop residue burning. Following this, various state-level measures were implemented to promote straw use and reduce residue burning. For instance, a High-Powered Committee (HPC) established by the High Court of Punjab and Haryana met in 2000, intending to promote appropriate machinery and straw use. The states of Haryana and Uttar Pradesh also forbade the burning of straw, and the state of Punjab developed a draft policy for managing and utilising crop residue (Casemine, 2015). With the technological innovation of the 'Happy Seeder Machine' in 2002 and perceived interest among farmers, the Department of Agriculture & Cooperation financially supported machine procurement by the farmers. In addition, extension agencies (like KVKs) helped to raise farmers' awareness of crop-residue management and the machine's utilisation.

Given that agriculture is a state subject, the state governments employed a variety of efforts, but the results were inconsistent. Discussing the intervention of the National Green Tribunal (NGT) on the issue, one of the representatives, in a semi-structured interview, elaborated on differential responses by the states and ensuing action. For instance, where the state government policies were not conducive to environmental interests, as in the case of Andhra Pradesh, cross-examination was instituted with a High Powered Committee, constituted of experts from the Central/State Pollution Control Board (CPCB/SPCB), agronomy institute, hydrology institution, and numerous Indian Institutes of Technology. At the same time, the lack of seriousness in the measures was also visible with the exacerbated condition of crop residue burning in the neighbouring north-western states, which produced severe air pollution in the Delhi-NCR region.

An environmentalist's legal case before the NGT (Kaushal, 2020) served as an eye-opener to the crop residue burning issue. The evidence-based assertions emphasised the incompetence of the statutory bodies (such as the CPCB/SPCB, state governments, and even ministries) in reducing air pollution caused by agricultural burning (Casemine, 2015). In response to the lawsuit, following the direction of the NGT, the Ministry of Agriculture and Farmers Welfare (MoAFW)

introduced the National Policy for Management of Crop Residue (NPMCR) 2014. The NGT has been a driving force behind efforts to reduce residue burning and put agricultural residues to better use. The media, especially during the pre-harvest season, emerged as a potent tool in disseminating awareness of the detrimental effects of crop burning and promoting sustainable alternatives.

Additionally, financial institutions played a crucial role, with the policy advocating for preferential crop loans for farmers committed to abstaining from crop burning. Different governmental bodies have been identified to spearhead specific interventions. For instance, state agriculture departments offered on-farm demonstrations. In terms of monitoring and evidence generation, the collaboration between the Central Pollution Control Board, the National Remote Sensing Agency, and the Ministry of Environment, Forests and Climate Change (MoEFCC) has been reflected. They employed satellite-based remote sensing technologies to track and reduce crop-burning incidents. Furthermore, ministries such as the Ministry of Agriculture & Farmers Welfare and the Ministry of Rural Development extended the necessary financial support to state governments, channelling funds through existing schemes to support interventions against crop residue burning. Further, on the Supreme Court's directive for control of Delhi-NCR pollution, a Comprehensive Action Plan (CAP) was prepared by Environment Pollution (Prevention and Control) Authority in 2017, following consultation with CPCB and the Delhi Pollution Control Committee.

The year 2018 was marked by various initiatives aimed at reducing crop burning and promoting its utilisation. The Ministry of New and Renewable Energy (MNRE) and the Ministry of Petroleum and Natural Gas (MoPNG), in collaboration with key energy sector players such as Indian Oil Corp. Ltd. and Hindustan Petroleum Corp. Ltd., focused on generating clean energy through biomass-based projects. In adherence to the National Policy on Biofuels 2009 by the MNRE, the MoPNG has announced the usage of agro-waste to produce ethanol. The MoEFCC launched regional projects to address stubble burning. The government schemes in the states of Punjab, Haryana, Uttar Pradesh, and the National Capital Territory of Delhi encouraged agricultural mechanisation for in-situ management of residues. The Ministry of Earth Sciences unveiled an Air Quality Early Warning System to predict pollution spikes resulting from stubble burning and other meteorological phenomena three days in advance. Moreover, research organisations are employing advanced techniques[15] to manage crop waste without burning it, using integrated strategies involving different stakeholders' collaboration.

Table 6: Identified Crop Residue Sector Stakeholders and their Interest

Government Stakeholders	Interest
Ministry of Agriculture & Farmers Welfare (MoAFW), Ministry of Environment, Forests and Climate Change (MoEFCC)	Environment sustainability and policy
Ministry of Petroleum and Natural Gas (MoPNG) , Ministry of New and Renewable Energy (MNRE)	Clean Energy Production; Power Generation from biomass
Cabinet Committee for Economic Affairs (CCEA)	Political and administrative coordination
State government	Environment sustainability and policy, pollution control

[15] The ICAR- Central Soil Salinity Research Institute (CSSRI), in collaboration with the International Maize and Wheat Improvement Center (CIMMYT), Climate Change, Agriculture and Food Security (CCAFS), the State Department of Agriculture, KVK, farmer's cooperatives, service providers, and farmers, managed one such incident that ended in zero burning in the "Sambhli" hamlet of the Karnal district in 2018. Recent innovations in stubble handling techniques, like the "Pusa bio-decomposer," have been produced by organisations like the IARI (Singh et al., 2018)

National Green Tribunal (NGT), Supreme Court (SC)	Improvement in air quality; public health, Influence on policies through green bench
Central Pollution Control Board (CPCB)	Pollution control
National Bank for Agriculture and Rural Development (NABARD)	Promotion of govt. policies through credit allocation
Research Bodies	**Interest**
NARS	Policy reforms through research and Technological intervention (Happy Seeder machine)
National Remote Sensing Agency (NRSA)	Promoting monitoring of crop residue burning using RS and GIS to enhance policy implications
Industry (Public/ Private)	**Interest**
Indian Oil Corporation Limited (IOCL), Hindustan Petroleum Corporation Limited (HPCL), Reliance, Entrepreneurs	Bioethanol production using biomass, Profit
Civil Society	**Interest**
Farmers/Farmers Association	Income diversification, Crop residue use diversification, Incentives/Subsidies
Confederation of Indian Industry (CII)	Supporting technology-based intervention
Mass/Print Media	Spreading Awareness

(Data source: Policy analysis, Literature Review and expert FGDs)

4.3.4 Livestock Feed & Waste Management

The formation of the National Dairy Research Institute (NDRI, 1923) and the National Dairy Development Board (NDDB, 1965) marked the efforts of the government of India to promote dairy development in India. NDRI aided the dairy-related research and education, while NDDB was steering the efforts of the economic viability of dairy units through aiding farmer communities. But, the landscape of livestock and animal husbandry looked different between the period before and after globalisation. From what was more government-owned and controlled institutions (like the animal husbandry departments at the state level) and producer-controlled dairy cooperatives, it diversified to include government-supported autonomous institutes, non-governmental organisations, and private players (Jothilakshmi et al., 2011). By the 1990s, policy interventions focused on lowering public sector involvement in the livestock delivery service system (Jothilakshmi et al., 2011). Livestock production and the expansion of the dairy industry required the support of the Department of Animal Husbandry & Dairying, while delivery and extension services were under the supervision of state departments (Phand et al., 2021).

While the government ministries, departments, and research organisations, such as State Agriculture Universities, the Indian Council of Agricultural Research, the Indian Veterinary Research Institute, and the National Dairy Research Institute, have made continuous efforts towards enhancing milk productivity and breed improvement, livestock feed and waste management have been an area of neglect due to insufficient funding support for research activities and extension services, as argued by Jothilakshmi et al. (2011), Birthal et al. (2012), and the Report of the Working Group on Animal Husbandry & Dairying (2011).

"As the dairy revolution was going on, without taking into consideration how livestock would get their grass and how livestock farmers would dispose of their dung and urine, the cooperative dairy

revolution only concentrated on creating supply chains and value chains". As quoted by the livestock research scientist during an interview, the above lines further corroborated the lack of effort in livestock waste management and handling processes. Although some NGOs, such as BAIF, had local-level influence in promoting alternative livestock in the late 1970s and 1980s, none took measures for the vast quantity of livestock waste generated. Extension agencies, such as the Agricultural Technology Management Agency (ATMA) and the National Institute of Agricultural Extension Management (MANAGE), played a crucial role in disseminating knowledge and capacity building of farmers, but their role in policy decisions has not been significant. Whereas livestock farmers were concerned with higher price realisation, dairy cooperatives were interested in the production and channelising of dairy products. Internationally, while GHG emissions were being highlighted in climate conversations, N did not attract policymakers' or environmentalists' attention in the context of the livestock sector (Raina et al., 2016). In light of the current emphasis on technology and innovation, FGDs highlighted a number of initiatives (including waste-to-energy projects) embarked on by government ministries, research organisations, and a few private companies. Nevertheless, the scope of these initiatives has been limited and will likely remain so until the technology is scaled up, as also emphasised by sector experts in the FGDs.

Table 7: Identified Livestock Sector Stakeholders and their Interest

Government Stakeholders	**Interest**
Ministry of Fisheries, Animal Husbandry and Dairying (MoFAHD), Department of Animal Husbandry and Dairying (DoAHD)	Reducing excessive fertiliser residues, Farmers participation, Improvement of livestock and dairy development
Ministry of New and Renewable Energy (MNRE)	Waste Management, Waste to Energy (e.g. Biofuels)
Directorate of Extension (MoAFW)	Effective implementation of extension initiatives
National Dairy Development Board (NDDB)	Strengthening Cooperatives; farmer livelihood
National Dairy Research Institute (NDRI)	Dairy production; commercialised dairy farms
Central Poultry Development Organisation (CPDO)	Poultry development; Sustainable rural livelihood
Agricultural Technology management Agency (ATMA), National Institute of Agricultural Extension Management (MANAGE)	Farmer driven and farmer accountable extension
Research Bodies	**Interest**
NARS	Pollution Control through research & technology, Technological Intervention, and adoption
Indian Veterinary Research Institute	Livestock productivity, health, and livestock improvement
Industry (Public/ Private)	**Interest**
Dairy Cooperatives	Optimising animal feeding, increasing efficiency of nutrient use for milk production
Civil Society/ Media	**Interest**
Livestock Farmers	Waste and manure management, Improved breed, and yield
NGOs	Waste and manure management

(Data source: Policy analysis, Literature Review and expert FGDs)

4.4. Stakeholder Categorisation: Analysing Current and Future Stakeholder Interests and Influence in the Agriculture Sector with Reference to N Management

Once stakeholders were identified and their roles and interests mapped vis-à-vis the identified policies, their nature of influence on key policy decisions was analysed using the interest-influence matrix. In this context, 'interest' indicates stakeholders' likely concerns and entailed benefits in the policy decisions and 'influence' indicates stakeholders' ability to resist or encourage change. Adapting the interest-influence matrix from Reed et al. (2009) and Yang et. al. (2015), the traditional 2 by 2 matrix was expanded into a 3 by 3 matrix to integrate the nuanced positions of various stakeholders and clearly categorise them based on their interest and ability to influence decisions at various points.

Experts were mobilised for this activity, and 3 rounds of focus group discussions (FGDs) were held to understand and analyse the relative interest and influence of all the agriculture sector stakeholders across the four sub-sectors. The findings of the FGD were later corroborated by revisiting literature and policy documents.

This exercise is crucial, and the information that can be drawn from the interest-influence matrix could be stakeholder categories of allies and opponents, showing who is likely to support and whom to resist the policy change and the level and nature of engagement required for each stakeholder for driving an influential N management agenda. This would require categorising stakeholders analytically based on their common or competing interests and influence. Figure 12 shows the nine analytical categories we developed to identify and categorise the key stakeholders and further suggests strategies for stakeholder engagement.

We identified the analytical categories of stakeholders: Subjects, Promotors, Key Players, Marginal Actors, Latent Actors, Potential Supporters, Crowd, Low Priority Actors, and Context Setters. 'Key players' have the most interest and influence in policy reforms and must be actively engaged and equipped to drive policy development. 'Promoters' have a strong interest but moderate impact on policy initiatives. These stakeholders must be actively involved because they can affect policy decisions. While 'Subjects' are interested in policy reforms, they often have no effect. 'Latent' actors neither support nor oppose policy reforms and progress. However, they have the potential and can be mobilised or engaged as the need arises. 'Marginal' actors and 'Crowd' are stakeholder categories with the least interest in policy reforms; they should be informed of policy debates and decisions but not forced to participate actively. Then, there are influential but uninterested stakeholders. They are 'Low Priority' actors and 'Context Setters'. While seemingly uninterested, these players might pose hazards for policy reforms, if not monitored. 'Potential Supporters' are actors with low interest in policy outcomes but strong influence. Their actions can directly influence policy decisions. Thus, they must be engaged and empowered to support reforms and execution. The following subsections explain the emerging stakeholder categories in fertiliser, organic farming, crop residue and livestock-related policies. As it will be evident in the following sub-sections and matrices, the positions of the key stakeholders vary in relation to the policies and agriculture sub-sectors in question. These positions are neither static nor independent of other stakeholder positions. Instead, with clarity in stakeholder categories, the stakeholder engagement strategy can be better informed to garner policy salience and reforms in the direction of sustainable N management.

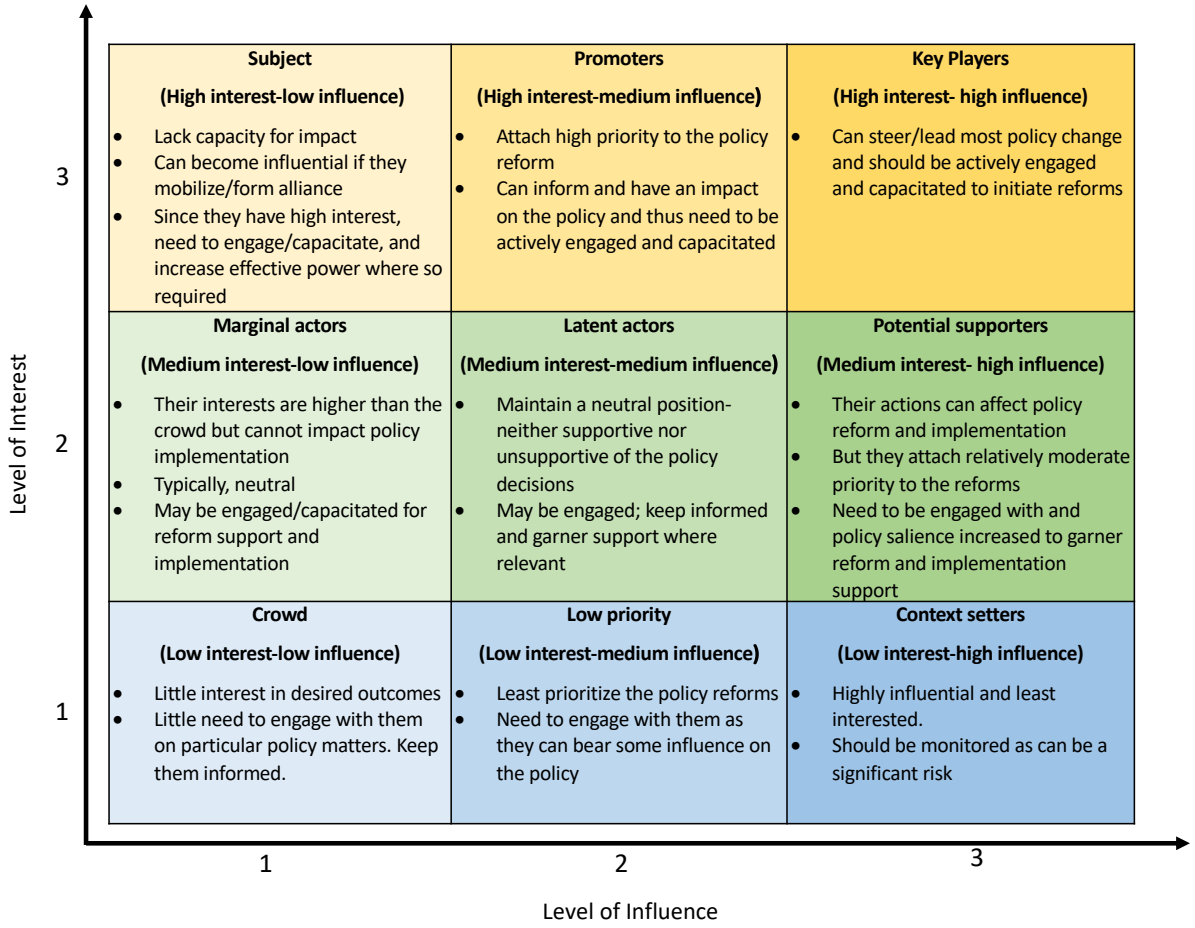


Figure 12: Stakeholder Categorization

While analysing the current stakeholder positions in the context of sub-sector policies, we also tried to understand how likely these positions would change and impact policy outcomes. In this case, policy outcomes mean policy changes and developments promoting sustainable N management in the agriculture sector. These were posed as separate queries during the FGDs and the stakeholder interviews. We asked the experts to identify and explain the likely changes in stakeholder positions (in the 3x3 matrix) and why they thought the changes would be important. These findings and responses from stakeholder interviews, were analysed to understand the future of policy and stakeholder landscape in N management.

4.4.1 Fertiliser Sector

a) Current Stakeholder Dynamics

Key Players: Ministries like the Ministry of Agriculture and Farmers Welfare (MoAFW), Ministry of Chemical and Fertilisers (MoCF), and Ministry of Environment, Forests and Climate Change (MoEFCC) are the key decision-making bodies that steer most of the changes with respect to fertiliser reforms in India. The MoAFW assesses the overall fertiliser requirement based on the initial requirements projected by state governments/UTs. The MoCF plans and monitors fertiliser production, fertiliser import and distribution, and fertiliser financial assistance management through subsidy/concession for indigenous and imported fertilisers. The MoEFCC ensures environmental compliance and enforcement in the fertiliser manufacturing industries in India. Besides, Cabinet committees like the Cabinet Committee on Economic Affairs (CCEA), which has authority over policymaking and implementation, and international organisations like UNEP, which are investing heavily in promoting N use efficiency, are also key players who drive fertiliser sector reforms. Because of their leadership role in policy change, these key stakeholders need to be actively engaged to initiate future reforms in the fertiliser sector.

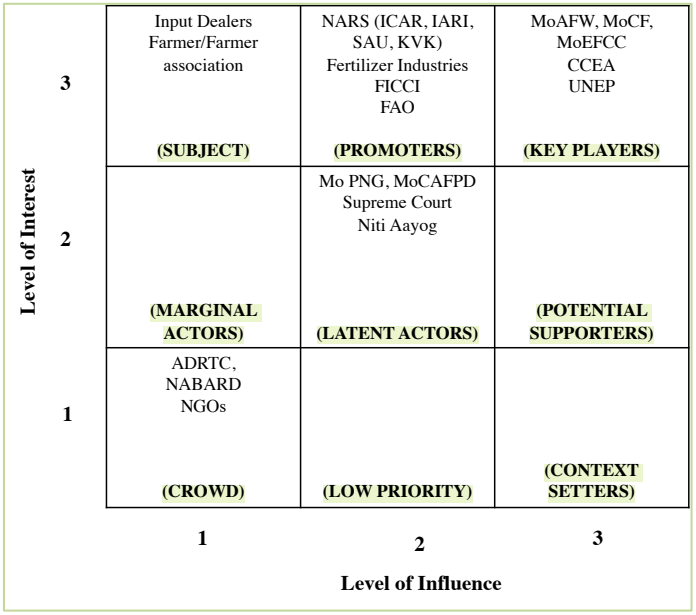


Figure 13: Interest-Influence Matrix: Fertilizer Sector

Promoters: Research bodies like the NARS (ICAR-IARI, SAU, KVKs) also have the highest interest in fertiliser sector reforms as they drive some of the innovations and experimental research on productivity and yield scenarios. However, their influence is in the medium category, as there is no direct engagement beyond research and recommendations. Similarly, the Food and Agriculture Organisation's (FAO) position as a promoter is explained by the fact that although it is highly interested in food security and health aspects, its role in policy formulation/advocacy is limited. However, they are likely to support a certain type of reform and thus are seen as actors to be actively engaged with. The fertiliser industries undoubtedly push for fertiliser reforms that maximise profit and production; however, their power to influence decisions is highly regulated and monitored by the Government of India. Like the key players, the promoters must also be actively engaged in future policy processes to drive evidence-based N management in the sector.

Latent Actors: As far as shaping the fertiliser sector reforms, both the Supreme Court of India and the Niti Aayog maintain a neutral position and, thus, are neither supportive nor unsupportive of the policy decisions concerning the fertiliser sector. While prior to 2010, when Niti Aayog was the Planning Commission, it had financial powers and could influence policies to a greater extent. Currently, it has assumed the role of a policy think tank acting as a latent stakeholder. Both stakeholders should be informed of the future policy processes for garnering support where necessary.

Subjects: Farmers and farmer associations are highly invested in these reforms, as they stand to be directly affected by any changes. Although they possess the potential for collective action, which could amplify their negotiating power, their individual influence on fertiliser sector reforms remains limited. This is largely because they often lack the organisational capacity, and access to resources and decision-making channels within the Indian policy landscape. It's important to note, however, that farmers and their associations are not a monolithic group; their interests and level of influence can vary significantly across different states in India. For example, farmers in North India have different demands than farmers in western and Southern Indian states like Maharashtra and Karnataka. This difference could have other affiliate reasons. In a normative sense, however, where decisions and impacts are made on the farm level, we find farmers playing a prominent role. Yet their influence level does not match the industry actors as they lack financial powers. Input dealers, like the farmers, have high interest but low influence. Their primary role is in implementing or influencing/maximising interest once policy decisions are made. They mostly influence reforms through local representatives and political leaders. These stakeholders should be equipped with the necessary skills and given more power where it is appropriate to facilitate future policy action toward N management.

Crowd: While CSOs are pivotal in policy advocacy and implementation instances, where they have actively voiced concerns about fertiliser use or influenced decisions in the fertiliser sector are relatively rare. It seems that CSOs have thus far shown limited interest in nitrogen management policies, despite their significant role in the actual implementation of such policies. While experts currently don't see an immediate need to engage with CSOs, it's worth noting that if engaged, these organisations could wield considerable influence, especially as such engagement would align with their broader environmental agendas.

b) Future Stakeholder Dynamics

The group of experts believed that in the future, decision-making agencies such as nodal ministries- MoAFW, MoCF, MoEFCC, CCEA, and UNEP will have the greatest interest and impact in effecting changes in the fertiliser sector. Thus, they will remain the ‘Key Players’ (See Figure 14). The ‘Latent Actors’ are expected to maintain the same position even with shifts in policy paradigm. For example, Niti Aayog, being a think tank, has no direct impact on policy decisions; nonetheless, it will continue to provide directional and policy inputs for decision-makers to consider. It was argued in the expert discussion that the other government stakeholders categorised as ‘Crowd’, such as the National Bank for Agriculture and Rural Development (NABARD) and Agriculture Development and Rural Transformation Centre (ADRTC), will continue to have the least amount of influence, as they only act as a refinancing channel to other sectors because they have no financial powers and no power in either the policy implications or the policy-making processes.

The farmers, especially organised farmer groups, could transition from being 'Subjects'—those affected by policies but with minimal influence over them—to becoming 'Promoters'—active and influential participants in the policy process. One of the experts posits that this transition is contingent on the ability of farmers and farmer groups to assert their influence within the political

arena effectively. In such a scenario, the expert explained, "*farmers could have a meaningful say in policymaking, a role that is currently limited given that most Indian farmers are small-scale cultivators*." The fertiliser industry is expected to remain focused on profitability, with no anticipated increase in its influence soon. Federation of Indian Chambers of Commerce & Industry (FICCI) may emerge as a significant force, potentially acting as an indirect lobbying body for the fertiliser industry, as per expert opinion. Input dealers and other market participants are not expected to see a decrease in their influence. It was also argued that the implementation of Direct Benefit Transfer (DBT) schemes could be a potential game-changer, which might marginalise the position of these dealers. However, as they currently form the primary link between farmers and the industry, they are likely to continue collecting commissions from the sales of urea and other fertilisers. These market participants could play a pivotal role in promoting balanced fertiliser use, as the timely availability, accessibility, and cost of fertilisers often shapes farm-level decisions. Regulatory interventions encouraging the use of biological fertilisers and traditional pesticides could open opportunities for input marketers to offer such substitutes in the agricultural market, thereby fostering a shift in farming practices. Looking ahead, agriculture entrepreneur models may gain traction, providing smallholder farmers with advisory services on efficient agricultural methods. NGOs, constrained by tight budgets under the current framework, are expected to have minimal interest and power in this context. Start-ups have the potential to contribute significantly to capacity building among farmers through grassroots training and demonstration operations. Experts suggest that while not all such initiatives will focus on sustainable agriculture practices, those aligned with climate-smart approaches are poised to play a vital role. Lastly, owing to their grassroots presence, Krishi Vigyan Kendras (KVKs) are anticipated to complement NGOs as last-mile extension agents, effectively delivering knowledge and services to farmers.

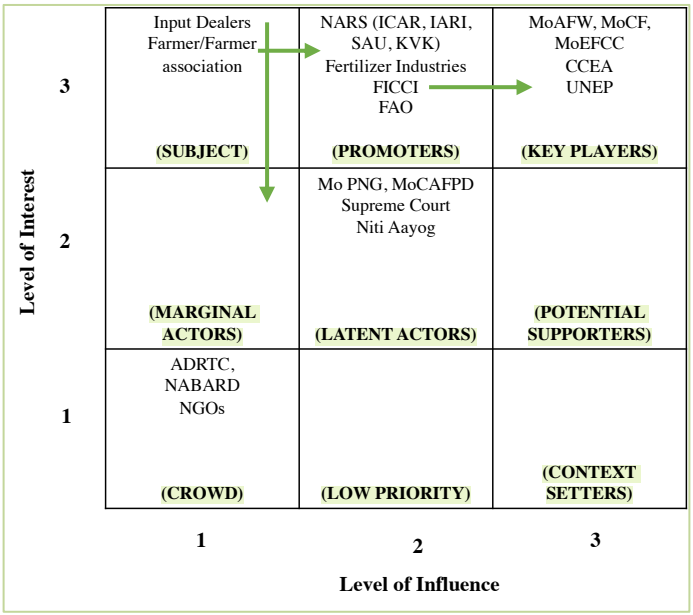


Figure 14: Future Stakeholder Dynamics: Fertilizer Sector

4.4.2 Organic & Sustainable Practices

a) Current Stakeholder Dynamics

Key Players: The Ministry of Agriculture and Farmers Welfare (MoAFW) has a high interest and influence in pushing the organic farming agenda forward, with policy promotion being its primary responsibility. Similarly, the Agricultural and Processed Food Products Export Development Authority (APEDA) and Export Inspection Council (EIC) are involved in policy execution while they control the exports. Thus, they have a high interest and influence in organic farming policies. Also, the experts perceive APEDA's increased importance in future, given the expanding international market for organic produce. According to the experts, these stakeholders have played a significant role in developing organic policies and will continue to do so.

Marginal Actors: Marginal actors (i.e. MANAGE and NGO) were recognised as executing and extension agencies who support the implementation of schemes/policies rather than having a direct role in shaping these policies. Despite their supporting role, their involvement in training and extension services can be instrumental in achieving enhanced policy outcomes, as they often help to bridge the knowledge gap between policy intentions and field realities for farmers. While these stakeholders typically maintain a neutral position in the decision-making processes related to organic farming policies, their level of interest in these policies is notably higher than that of more passive groups, such as the consumers.

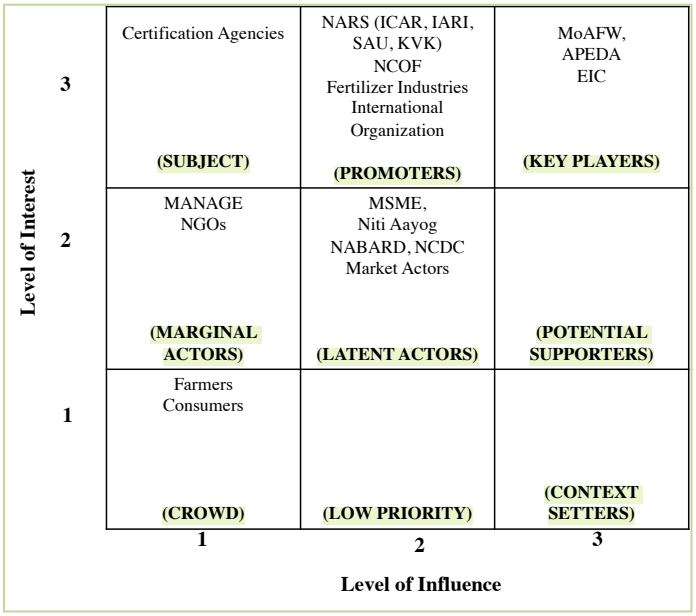


Figure 15: Interest-Influence Matrix: Organic Sector

Crowd: Farmers (producers) and consumers were perceived to have lowest interest and influence in organic farming policies as the market for organic produce/ products is not mature in India. The demand generation here is also affected by supply. Organic foods are also more expensive. Organic markets will accelerate only if massive demand drives it. The organic farming system's distribution framework is inadequate. Though farmers are becoming more aware, the current state of technology and institutional context places them at the bottom of the list. Experts contend that these groups hold little influence in formulating organic farming policies and anticipate no significant changes unless the market for organic products expands or consumer demand increases.

Promoters: Research bodies like NARS, National Centres of Organic Farming (NCOF), and CSIR are the technology demonstrators who are well-funded with research capacities and have high interest and medium influence in pushing forward the shift to organic farming practices in policies. In fact, the NARS bodies were previously the largest producer of biofertilisers but now focus solely on research and attach high priority to balanced and sustainable use of fertilisers while promoting organic practices. These stakeholders play an important role in shaping policies through evidence-based research. As such, they should be actively engaged and capacitated for long-term involvement in organic agricultural policy. This necessitates the allocation of research funds for organic farming-driven research and development.

Latent Actors: The Ministry of Small & Medium Enterprises (MSME), organisations like NABARD, National Cooperative Development Council (NCDC), and Niti Aayog have medium interest and influence in organic farming policies. Currently, these actors neither support nor oppose India's agricultural reforms involving organic practices. The reason could be that there is insufficient market size for them. While these actors are dormant, they can become significant if the government encourages a well-organised organic agriculture sector.

Subject: Third-party certification agencies play a pivotal role in the organic agriculture sector as they ensure quality, prevent fraud, and enable international organic trade. Since the sector does not have a well-organised market yet, these third parties do not have the power to influence organic sector policies. Interviews with organic farmers revealed that the organic certification takes three

years, it is time-consuming and inconvenient for small-holding organic farmers with limited income. Most farmers interviewed from Haryana thus explained that they seek refuge in collective action. They formed a farmers' producer organisation to increase volumes and establish sustainable market connections. Initially, 80 farmers joined the group, but owing to certification challenges and a lack of local markets, just 12 farmers remain. If there is a possibility that these stakeholders will develop into influential organisations, they will require further training and resources to maximise their impact.

b) Future Stakeholder Dynamics

When asked about the future changes in stakeholder positions, the experts concurred that stakeholders at the top of the decision-making chain (MoAFW, APEDA, and EIC) will remain critical in enacting policy changes that promote sustainability. However, they also discussed the possibility of growing awareness among consumers about the harmful effects of chemical fertilisers and the need for a healthy lifestyle, which will have a spiralling impact and encourage farmers to switch to organic farming. The group felt that Niti Aayog's position as a 'Latent Actor' will not change (see Figure 16), but they will remain important in policy formulation. NARS, PFOs and NCOF will continue to provide scientific support for the transition to organic farming, but their influence and interests will be limited. In the future, research institutes are predicted to have more policymaking authority if the government provides appropriate funding and is driven by farmer viewpoints. In one of the FGDs, the experts also stated that the certification agencies "*might become more influential in future, provided they become more transparent and accountable in the entire certification process*". The views of farmer groups (practising organic farming in Haryana state) were also considered in understanding the future scenario. The farmers concurred on the need for price support, subsidies, improved extension services and residue management and expressed interest in establishing market links for their organic produce for sustained profits. The experts at the FGD also felt that as the organic market expands, market actors will assume a greater role and thus shift from being 'Latent' actors to 'Promoters'. Strengthening the market will also encourage more farmers towards organic farming. According to experts, the fertiliser industry is aware that the government subsidies it currently receives for chemical fertiliser may not be sustainable in the long-term, which could spur their interest toward biofertilisers and bio-stimulants to grow in the future. As experts outlined, NGOs may be expected to be a 'Promoter' as extension organisations in disseminating sustainability-oriented policies addressing N challenges in agriculture.

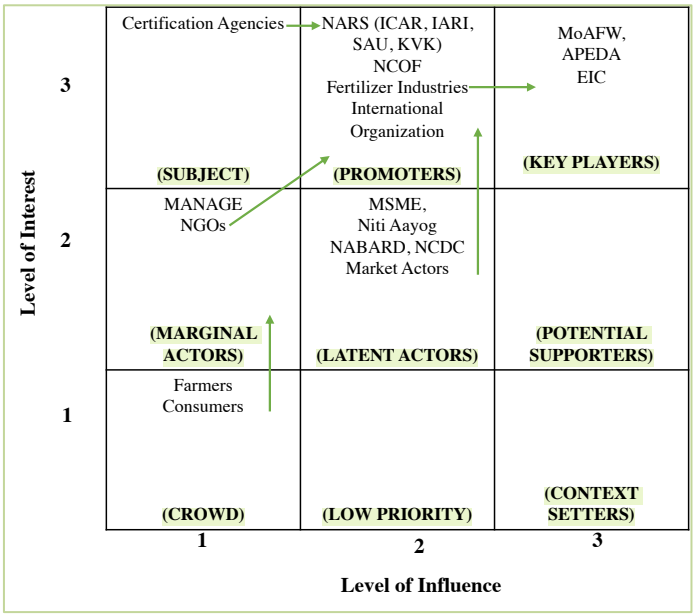


Figure 16: Future Stakeholder Dynamics Organic Sector

4.4.3. Crop Residue Management

a) Current Stakeholder Dynamics

Key Players: The Ministry of Agriculture and Farmers Welfare (MoAFW), Central/State Pollution Control Board (CPCB/SPCB), National Green Tribunal (NGT), Ministry of

Environment, Forests and Climate Change (MoEFCC), and Supreme Court (SC) have the highest level of interest and influence in pushing forward reforms on crop residue management due to increasing air pollution and public health concerns in India, particularly in north-western India. These actors have steered most of the policy decisions, especially formulating the National Policy on Crop Residue Management, 2014. The NGT has the powers, but in the capacity of an adjudicatory body rather than a monitoring or regulatory body. It has extensive macro-environmental authority, with reference to soil, groundwater, air, and land, but not directly to agriculture. It has nonetheless handed down a slew of environmental rulings, many of which indirectly impact agriculture. According to experts, the Supreme Court's authority is growing, garnering government attention. Yet, on many occasions, the government does not provide adequate assistance or attention to the NGT, which limits its influence. This discrepancy in government response was corroborated through stakeholder interviews with NGT personnel. They described a pattern where the MoEFCC has frequently not responded to complaints and notifications issued by the NGT. These unaddressed issues span a range of environmental challenges, including air, water, and land pollution stemming from the agriculture sector. This has led to a situation where regulatory bodies—including CPCB/SPCB and water authorities—are left in a challenging position. They find themselves held accountable for not enforcing these limits and regulations despite the lack of engagement or guidance from the MoEFCC, the key governmental authority responsible for environmental matters. In the context of rapidly changing and complex environmental conditions and decisions, experts in our discussion opined that both the NGT and the Supreme Court are important judicial entities, and they ought to be involved in upcoming policy discussions in areas where their support is required the most.

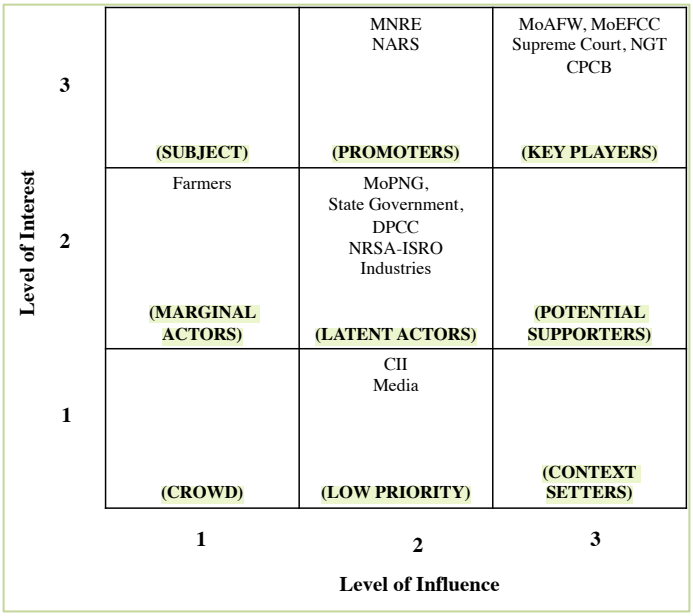


Figure 17: Interest-Influence Matrix: Crop Residue Sector

Promoters: The Ministry of New and Renewable Energy (MNRE) was classified as a 'promoter' due to its interest and involvement in various waste-to-energy interventions currently in the pipeline. Likewise, NARS institutions have been instrumental through high-quality research and farm-level technology development. Both institutions can play a significant role in shaping and influencing crop residue management (and preventing burning) through technological interventions (especially waste-to-energy) if engaged actively in the key policy areas.

Latent Actors: Ministry of Petroleum and Natural Gas (MoPNG), State Government, Delhi Pollution Control Committee, Industries, and National Remote Sensing Agency (NRSA) were classified as latent actors and were placed in the middle of the matrix with a medium level of interest and influence. These actors are important in crop residue management; however, their influence is questionable. For instance, MoPNG requires changes in their processes and systems to use the crop residue for energy production, which involves cost issues and, thus, maintains a neutral position in decision-making. While state governments play an important role in curbing the stubble-burning issue at their level, they do not show high-level interest in the issue due to the costs involved. In the industrial sector, the push towards renewable energy options has spurred

some small-scale private entrepreneurs to manufacture organic manure and inputs using crop residues. However, these attempts are sparse. Likewise, in the research domain, the NRSA assists in implementing policy via monitoring of crop burning. However, the government mainly drives the interest, and NRSA does not have any influence.

Marginal Actors: Farmers currently have a medium level of interest and very low influence on crop residue management policy reforms. During the interviews, farmers stated that there is no economically viable solution or technology to control stubble burning and that they would like government assistance in the form of subsidies for machinery inputs (zero seed drill, happy seeder, etc.) because it requires additional expenditure and time. Otherwise, given the extremely narrow time window between harvesting and sowing consecutive crops, they find it difficult to act.

Low priority: The Confederation of Indian Industry (CII) and media are placed in the low level of interest and medium influence. While both CII and media institutions can influence policy reforms by giving voice to marginal actors, they tend to attach shallow interest to the issue of crop residue burning.

b) Future Stakeholder Dynamics

As suggested by the experts, in the context of agricultural residue handling and management, nodal government agencies like the MoAFW, MoEFCC, along with CPCB, NGT and Supreme Court, will continue to be the 'Key Players' in future, exercising maximum decision-making authority (see Figure 18). Drawing from the experiences of judicial intervention in pollution incidences, the expert from the NGT expressed that vesting certain monitoring and enforcement power with statutory bodies, like the tribunal itself, might have far-reaching consequences in waste management. Thus, the judiciary can also be seen as a 'Key Player' in crop residue management. The NRSA-ISRO, as a premier research organisation, will continue to be a 'latent actor' through monitoring and analysis of fire scenarios. The experts did not perceive much deviation in the role of NARS institutions, yet felt that their persistence was critical in solving the pressing problem of residue handling and management.

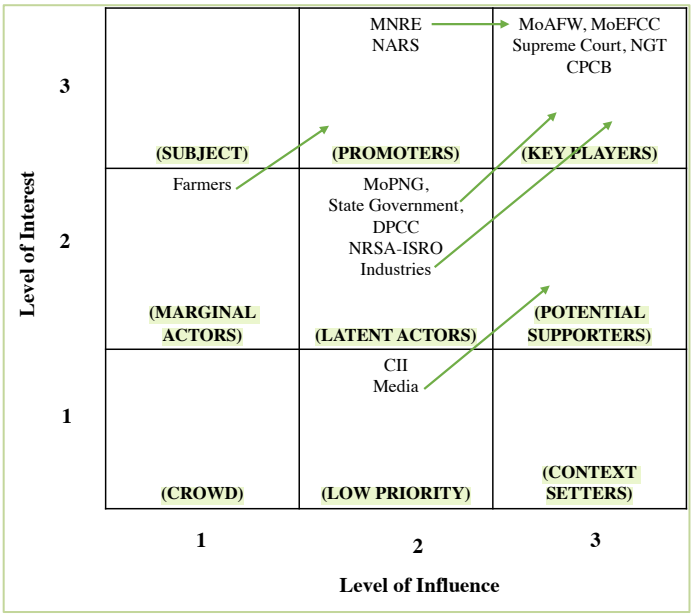


Figure 18: Future Stakeholder Dynamics: Crop Residue Sector

To enable farmers to manage crop waste sustainably, experts from the focus group discussion emphasised the need for government incentives and extended support. Since many farmers cannot afford the expenses associated with alternative crop waste management practices, government assistance could empower them to become 'Promoters'—active and influential participants in the policymaking process—rather than passive subjects of policy. Experts suggested that building confidence among farmers and fostering peer learning are key steps towards encouraging more sustainable practices. Developing a value chain for crop residue is another essential component, turning waste into a resource for energy generation plants. For this transformation to occur, experts argue that major energy firms, such as Reliance, Indian Oil Corporation Limited, and Hindustan

Petroleum, must invest in scaling up technologies for projects like Hydrogen Cell Energy and Bio-ethanol production. These initiatives could harness energy from agricultural residue while providing farmers an additional income source, creating a win-win situation. According to experts, the media, could assume the role of a 'Potential Supporter' by helping prevent stubble burning through awareness campaigns and by critically evaluating and questioning government policies related to agricultural waste management. Furthermore, experts stress that the active involvement of key ministries, such as the MNRE and the MoPNG, is vital for facilitating projects and programs focused on biomass. Their engagement as 'key players' could be pivotal in shaping and driving forward a coherent and effective national strategy on this front.

4.4.4. Livestock sector

a) Current Stakeholder Dynamics

Key Players: The Department of Animal Husbandry and Dairying (DoAHD) is the key player in influencing decisions on livestock waste management policies in India. The ministry has been promoting and executing practices that recycle animal waste back into the farm. Such players have the highest interest and influence in steering policy reforms and should be actively engaged in policy decisions pertaining to livestock waste management.

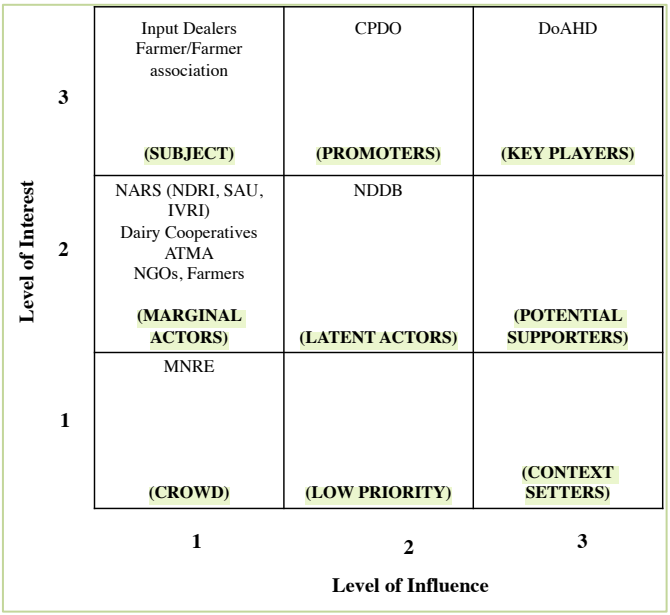


Figure 19: Interest-Influence Matrix: Livestock Sector

Promoters: The Central Poultry Development Organisation (CPDO) was identified as one of India's promoters of livestock waste management policies. India is the second largest producer of poultry. However, the innovative waste management methods suggested by CPDO are currently only on paper, though in future, they do intend to promote the palletisation of dried manure and other alternative systems for manure management. For these policy decisions to be realised, actors like CPDO must be engaged and capacitated to have a more significant impact on the policy.

Latent Actors: Organisations such as the NDDB, which play an integral role in the promotion and planning of dairy and agricultural development programs in India, are currently focusing primarily on the development of the dairy sector, leaving the issue of waste management unaddressed. As influential actors in the livestock sector and having the capacity to influence the larger dairy network, their potential to facilitate livestock waste management at the grassroots remains unrealised and latent, expressed the experts in the FGD and interviews.

Marginal Actors: The Agricultural Technology Management Agency (ATMA) is available for the dissemination of technology therefore, interest is medium, but its influence was perceived as low as it does not have the power to influence policy changes. Similarly, NDRI, which is not related to dairying activities but more to processing activities, plays a marginal role in policymaking. Likewise, academic-oriented research organisations' role is to develop genotypes

and provide basic research under the government's guidance. Therefore, all the NARS institutes and SAUs were also perceived to occupy the same position, as these were primarily involved in animal breeding. SAUs have done great work in expanding hybrid cattle with the focal point of increasing milk production. However, none have actively worked or provided evidence-based research on livestock waste management. The dairy cooperatives may have influence because they dominate the milk production and supply side; however, their interest in waste management is low, and no integrated system exists. Though livestock is a means of livelihood for many farmers, they hardly have the power to influence policy decisions. Similarly, except for large-scale NGOs (like the BAIF), most have only local influence on decisions related to alternative feed and cattle development.

Crowd: The Ministry of New and Renewable Energy (MNRE) was identified as a crowd because it was not perceived to have an interest in the desired outcomes. Its policies and interventions related to biogas production have not yet scaled up with respect to livestock waste management. According to the experts, currently, there is little need to engage with MNRE. However, it should be kept informed of the policy decisions for future engagement and support.

b) Future Stakeholder Dynamics

Discussing the future scenario, the sector experts in FGD stated that the decision-making authority over the expansion of the livestock sector will continue to reside with the DoAHD. Further, it was indicated that the MNRE could only have a greater impact if they broadened their focus on waste management and scaled up their energy projects. For organisations like the NDDB (Figure 20), it would be difficult to make a significant impact unless they promote N management strategies other than animal husbandry. The future effects of the research institutes could be modest, but only in the context of actions for animal nutrition-related research and development. The NGOs and extension agencies could perhaps be more motivated to address the concerns of waste and feed. Other than that, stakeholders, including co-operatives and farmers, were predicted to occupy the same positions going forward because their primary concern would be profit generation rather than managing waste. One of the research experts added about farmers' positions, *"Livestock farmers' voice is not much in comparison to the crop farmers, and they have nothing to do with N management policy but only concerned with the realisation of better prices."*

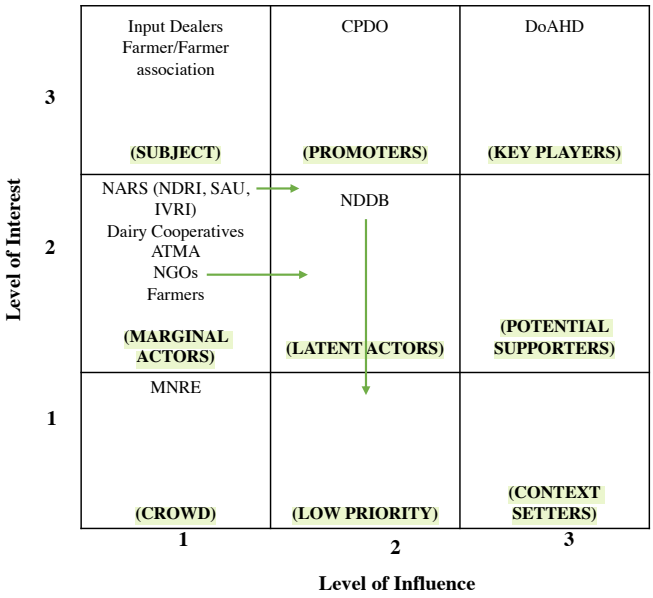


Figure 20: Future Stakeholder Dynamics: Livestock Sector

To summarise the expert comments and additional insights provided through stakeholder interviews, farmers and farmer groups are likely to increase and have a greater impact on policy reforms in N management in all agricultural sectors if their political presence is reinforced. Similarly, India's fertiliser industry and industry associations are expected to acquire greater influence if they recognise that the government is committed to lowering subsidies on nitrogenous fertilisers and concentrating instead on bio-fertilisers and bio-stimulants. Perhaps civil society

organisations and media groups are required to take up their role and become more responsible towards spreading awareness regarding N management concerns and reaching the public in areas like crop-residue management and organic farming. The nodal ministries, on the other hand, will continue to play a significant role even in the future, with other ministries like the Ministry of New and Renewable Energy and the Ministry of Petroleum and Natural Gas also becoming significant stakeholders, especially regarding waste management.

In the next section, we discuss the key barriers and opportunities perceived by the stakeholders at the policy and practice levels.

4.5. Stakeholder Perspectives on Policy and Practice: Barriers and Opportunities

The policy analysis and stakeholder engagement exercises (through focus group discussions and interviews) were revisited in this last stage of agriculture stakeholder analysis to understand the policy barriers and opportunities with respect to effective nitrogen management in agriculture (See Figure 21). The findings were corroborated with the existing literature to understand the broader context and draw interpretations. The sub-sector-wise findings are discussed in the following sub-sections.

4.5.1. Fertiliser sector

Although the initial focus of the fertiliser policy on enabling high fertiliser consumption and increasing food production may have been deemed successful, it nevertheless resulted in significant N problems throughout the agriculture sector. Given the barriers, which include farmer knowledge of nitrogen use efficiency, price differences, heavy subsidies etc., policy measures that encourage optimal nutrient application are needed to tackle the N problem. These include providing farmers with extension services, encouraging crop diversification, and taking a logical and balanced approach to fertiliser subsidies. Therefore, to achieve effective and sustained growth, it may be beneficial to establish a stable policy environment in the fertiliser sector.

4.5.1.1 Fertiliser Sector: Barriers

Farmers' Knowledge of Fertiliser Use: The farmers' knowledge of fertiliser application elicited mixed opinions among the interviewed stakeholders. Of them, a few asserted that farmers lack an understanding of the optimal amount of fertiliser required by crops, leading to increased input usage. Conversely, other stakeholders asserted that farmers are becoming more informed about the harmful effects of excessive fertiliser usage and are complying with recommended application rates. During the semi-structured interviews, farmers exhibited a sound comprehension of balanced fertiliser usage but also acknowledged that the proportion of farmers with optimum knowledge varies. The discussion shed light on the knowledge gaps among farmers, for instance, in cases of decreased crop yields and visible plant attributes, such as reduced green colour, which compels them to over-utilise fertilisers in their farmlands. These knowledge gaps are attributed to the lacunae in delivering extension services for training and demonstrations to farmers.

Pricing and Subsidies on Chemical Fertilisers: Most of the stakeholders interviewed and the literature findings underlined that subsidy[16] on chemical fertilisers served was a determinant for a heavy reliance on chemical fertilisers when discussing previous policy initiatives. Heavy price discrepancies and subsidies tempted farmers to favour N-based fertiliser which further resulted in nutrient imbalances in the soil.

"Increase in fertiliser dependence came as an unintended fallout of Green Revolution, encouraging monocultures, especially, at the cost of cereals, legume rotations which meant that a natural process of N fixation which came through the pulses and legumes was no longer taken advantage of". This response from the semi-structured interview of the research scientist argued on the current cropping pattern driving increased fertiliser application. Thus, the fertiliser policy reforms and scheme (for instance, the NBS scheme), although aimed at reducing the share of N in total fertiliser use, ended up encouraging imbalance by favouring higher use of N relative to others (Fertiliser Use and Imbalance in India, 2015).

4.5.1.2 Fertiliser Sector: Opportunities

Strengthening of Extension Services and Capacity Building of Farmers: To achieve policy targets efficiently, interviewed stakeholders suggested strengthening on-farm extension services, including manpower training and supply of inputs/new technologies. They asserted that the government must leverage the technical expertise of research organisations and the field presence of agencies (like KVKs) to demonstrate efficient fertiliser usage to farmers. The suggestions were geared towards removing technology barriers and ensuring smooth transfer and adoption, which requires strengthening extension agencies and regularly monitoring the progress.

Pricing and Subsidy Reforms: For a balanced utilisation of N fertiliser, the experts argued that levying greater taxes on chemical fertilisers might motivate farmers to look for options other than nitrogen fertilisers. For policy reforms, it was recommended by the experts that the government should use a gradual urea decontrol system based on progressive urea price inflation. Besides, including urea in the nutrient-based subsidy scheme will lead to adopting corrective measures to compensate for skewed urea pricing structures, allowing for a more balanced nutrient pricing.

Crop Diversification: While pointing out the excessive dependency on fertilisers, the research organisation stakeholders underlined that the present scenario might correspond to inappropriate market and incentive structures that need to be shifted in favour of diversified cropping patterns to encourage diversity. As crop diversification has been proposed to increase the efficiency of N fertilisation, it could lead to optimised application of nitrogen (N) fertilisers to reduce adverse economic and ecological effects. During the interviews, the farmers also argued that the government should alter the MSP criteria in a way that it does not remain confined to fewer crops (mainly rice and wheat) but rather encompass additional crops (for instance, oilseeds, legumes, and horticulture) that could serve as a better alternative for human health and environmental sustainability. Further, as quoted by the research scientists, *"There cannot be crop diversification without procurement"*. Thus, for crop growers to change their behaviour regarding cropping patterns, it was deemed necessary that the government take advantage of its influence as the largest buyer.

[16] Total subsidy on chemical fertilizers is steeply rising every year. In 2020–21, the annual subsidy bill was Rs 1,31,230 crore, more than 10 times the subsidy bill of Rs 12,908 crore in 2001–02. (Khurana and Kumar 2022)

4.5.2 Organic Sector

The current discourse and policy impetus on organic farming practices is triggered by unsustainable and aggressively chemical fertiliser-based farming practices that have led to diminished soil nutrient levels/fertility and reduced yields. Some of these difficulties, emerging from discussions with farmers, include the absence of markets, poor-quality organic inputs, and costly and complicated organic certification processes. As it emerged from expert discussions, strong government support intended to promote organic practice through an expanding marketplace, infrastructure facilities (such as state laboratories) and credible certification agencies, availability of quality inputs, and raising awareness would be essential for long-lasting sustainable reforms.

4.5.2.1 Organic Sector: Barriers

Lack of Markets for Organic Produce: The farmers expressed concern over the availability of markets and reliable and affordable certification processes as primary reasons for their reluctance to switch to organic cultivation practice. Experts' insights added that organic produce is still exclusively purchased by a few affluent parts of society, quoted as *"the price increases with certification and labelling processes; hence, the average buyer is put off from buying organic produce"*. So, the problem was reflected at two levels: first, the reluctance to switch to organic farming due to productivity and pricing constraints; and second, the absence of assured markets. Further, it may also be considered that farmers in many states of India cultivate organically as part of their tradition, but problems of quality, storage, productivity, etc. remain.

Lack of Raw Material and Quality Assurance for Organic Fertilisers: While addressing sustainability in the long run, most stakeholder discussions revolved around promoting organic fertilisers. However, there are challenges concerning the availability of adequate amounts of organic manure/residues for boosting the production of organic fertilisers. For instance, according to official data, India produced 3.88 million tonnes of organic fertilisers in 2020-21, a significant fall from the 338.72 million tonnes produced in 2017-18 (DTE, 2018). This could be attributed to the low utilisation of production capacity, which is tied to limited demand, which, in turn, is linked to limited government assistance for the promotion of non-chemical fertilisers (Khurana & Kumar 2022). Furthermore, the existing regulatory system lacks sufficient quality control mechanisms for organic fertilisers- as reflected through stakeholder interviews with research scientists and organic farmers. Laboratory infrastructure is missing in many states, while many have underutilised facilities. While speaking with farmers, they narrated how low-quality and spurious organic fertilisers were widely available, as a result of which they found commercial organic input unreliable. When corroborated with literature evidence, the state government's fertiliser procurement through tenders at low prices was held responsible for the poor quality of bio/organic fertilisers being distributed (CSE 2022). Efforts are being made at the state and local levels; nonetheless, these efforts are insufficient, and more extensive action is required.

Credibility of Certification Agencies: While unorganised organic markets are already a challenge for farmers, the existing certification procedures make the situation even more challenging and deter them from growing crops organically. As mentioned earlier, the current certification system is inconvenient, time-consuming, and costly, and there is scepticism about the process' validity. The experts from research organisations confirmed the drawbacks of the certification agencies and inefficient labelling systems.

4.5.2.2 Organic Sector: Opportunities

Strengthening Organic Markets and Certifying Processes: There is a need to establish strong drivers, such as a vibrant market that could benefit farmers while addressing existing barriers to adopting organic and natural farming. The interviewed organic farmers envisaged a decisive localised network with marketplaces exclusively for organic growers, allowing for a more effective distribution system to aid the transition to organic agricultural practices. Further, strengthening the organic market would require linking farmers with the domestic and worldwide supply chains, which in turn could fetch better prices to farmers for their organic products. As indicated during the farmer's interview, network development- for instance, direct contact with the consumers or the dealers/retailers that fetch the farmer better price should be aided, which is not the case now. Government agencies must develop a transparent testing protocol and certification system to allow a flourishing market of authentic organic products. More certifying organisations must be established in proximity to the farms/procurement centres through partnerships between the central government and state governments. Sustaining these initiatives would also require budgetary help and coordination within government organisations.

Policy Support to Encourage Organic Practices: As expressed by the sector experts in the FGD, switching entirely to organic farming would be a rash option. Instead, a methodical approach, gradually increasing the usage rate of organic matter, could help increase the yield over time. This would require bringing together different ministries and several programmes and outlining the Centre-State relationship in terms of funds, accountability, and coordination. Moreover, the research organisations should carefully guide the decisions on the percentage area under organic cultivation. The regulatory frameworks must help the farmer transition to organic farming practices; for instance, the organic food pricing policies should be scrutinised to guarantee the financial return to the producers. Meanwhile, efforts towards making organic fertilisers economically viable for the farmers would be imperative. Thus, the pricing and distribution policy must consider the affordable, timely, and adequate bio-fertiliser supply.

Maximising Organic Fertiliser Availability and Quality Monitoring: A collaborative approach between the Centre and State authorities was deemed imperative for formulating strategies to augment industrial production capacities and institutionalising a robust quality assurance framework. Moreover, a multi-tiered strategy would be required to encourage their usage. For instance, states must establish a reliable organic supply chain that taps into the unutilised potential of agriculture residues, agro-industrial waste, and urban organic waste to feed into the city's composting units. A decentralised testing infrastructure should also be encouraged at all levels, with a directed policy boost on enhancing the testing capacity of labs. Policy efforts need to concentrate on boosting the testing capacities of these labs via norms and regulations for promoting the utilisation of these fertilisers. Greater participation of research groups was deemed vital if prompt and efficient testing procedures and facilities for certifying organic produce were to be established. Presently, only a few private enterprises supply organic fertilisers, and that too at significantly higher prices. Therefore, subsidy mechanisms on organic fertilisers could motivate farmers to change their fertiliser preferences.

4.5.3 Crop Residue Management

Despite several government measures to curb agricultural residue burning by farmers, the alarming air pollution increase because of residue burning highlights the underlying policy

practice gaps (Lan et al., 2022). These include the difficulties farmers encounter because of a lack of labour and time between subsequent crops, as well as some others, such as an inadequate focus on alternative residue uses and inefficient implementation of the existing measures. The government must devise incentive or subsidy-based models for the farmers, capitalise on residue waste, build capacities, and provide technological solutions at affordable prices, thereby adopting an interlinked strategy in order to overcome residue management constraints, as explained by the experts.

4.5.3.1 Crop Residue Management: Barriers

Insufficient Focus on Residue Management: The current challenge in crop residue management pertains to inadequate regulations and monitoring mechanisms, with existing provisions lacking proper enforcement. Experts also argued that the problem lies with the mechanised rice and wheat cropping pattern of Northwest India, which does not leave enough time between paddy harvest and the sowing of wheat. In addition, the policy measures focus merely on prohibiting crop burning, accompanied by strict penalties for farmers. There was a stark absence of a bigger picture that combines alternative uses of residues with existing measures. Smaller initiatives by the CSOs and others faced the challenge of scaling up.

Farmers' Barrier to Sustainable Crop Residue Management: While the farmers expressed their constraint to burn the residue on the field due to a shortage of labour and time, other stakeholders added the lack of extension support from the government agencies as a factor. Existing technologies such as the Super SMS (Straw Management System) and Happy Seeder Machines are insufficient in terms of farm mechanisation (Dhaliwal et al., 2011) and come at a high cost and are thus unaffordable for farmers.

4.5.3.2 Crop Residue Management: Opportunities

Diversified Use of Residue Management: Both literature and expert opinions suggested that the multifunctionality of crop residues (for instance, in terms of soil nutrients, power generation, and biofuel production, etc.) should be evaluated for wide-scale management of residues. The government needs to focus on "nexus thinking"[17] towards promoting a higher level of integration of environmental resources that goes beyond disciplinary boundaries (Bhuvaneshwari et al., 2019) – in other words, cross-disciplinary and cross-sectoral partnerships must be promoted. Policy reform should consider the formulation of state-level policies with clearly guided principles on alternative applications. During the interviews, farmers and researchers suggested that the government should govern appropriate capitalisation of residues, implying that the government may procure crop residue in return for subsidies for farm inputs to farmers and put it to use in energy projects. Future government initiatives should concentrate on increasing residue utilisation under such programmes; similarly, energy firms and NGOs should invest in making such projects viable. Most importantly, a well-coordinated monitoring system for burning incidences would be crucial for strengthening policy endeavours.

[17] Even though agricultural residue burning affects many sectors, including the environment, agriculture, economy, social aspects, education, and energy, government efforts are mostly centred on agriculture and energy, which should not be the case considering the present scenario and efforts should thrive towards an inter-sectoral approach for encountering N problems.

Incentives to Farmers: The experts believed that instead of imposing strict norms and regulations that are difficult to comply with, incentivisation and affordable technological intervention could be provided to the farmers for better management of crop residues. It was argued that the system lacks policies suited to farmers' requirements. During the interview, members of the farmer-producer organisation (FPO) argued that money allocation on advertisements (for instance, putting up posters/banners), could be redirected to incentivising FPOs. This could be an efficient way of a decentralised awareness campaign (via training workshops and demonstrations) among farming communities on crop residue management. The delivery of extension services via training, demonstrations and cooperation should be strengthened to allow in-situ stubble management.

4.5.4 Livestock Waste Management

Considering increasing dairy production and insignificant consideration of the waste and feed handling mechanisms during the process, the livestock sector has been identified as one that lacks serious attention to the issues of N management. Enforcing rules and regulations, devising a decentralised system to regulate pollution, supporting research on alternate waste utilisation methods, and taking a methodical approach to capitalising waste through business models are all necessary to fill the void in waste management across the livestock sector.

4.5.4.1 Livestock Waste Management: Barriers

Feed and Waste Handling: During the interviews, most stakeholders pointed out the lack of technological interventions for efficient waste treatment and dairy by-product utilisation. With reference to waste handling and management, lacunae at all levels of government departments, research institutes and cooperatives were highlighted. The stakeholder interviews marked the absence of effective government strategies and regulations for managing N losses, along with existing enforcement issues. Further, the livestock sector is argued to be grossly under-invested and neglected by various extension and financial institutions (NAAS 2002, Birthal et al., 2012).

4.5.4.2 Livestock Waste Management: Opportunities

Emissions and Effluent Regulations: Appropriate enforcement of emission regulations and standards is required to manage massive quantities of livestock waste. The government ministries and departments must primarily bring that about. The sustainability of these efforts requires robust institutional support through funding extension services and research institutions. While extension agencies should strengthen the capacities of farmers, researchers need to sharpen their thrust on waste utilisation mechanisms.

Waste Capitalisation: Interviews with the researchers highlighted the urgent requirement for a logistic business model for a systematic approach that collects waste and further capitalises it as manure for farmers while scaling up local employment programs. Developing a decentralised system (such as training and demonstration facilities and assistance centres) accessible to all farmers was thought to be vital for enabling waste management. Considering the scale of the problem and fragmented efforts at the farm level, the stakeholders expressed that cooperatives may redirect their efforts beyond milk procurement and distribution towards establishing of waste processing channels and provide training and incentives to farmers.

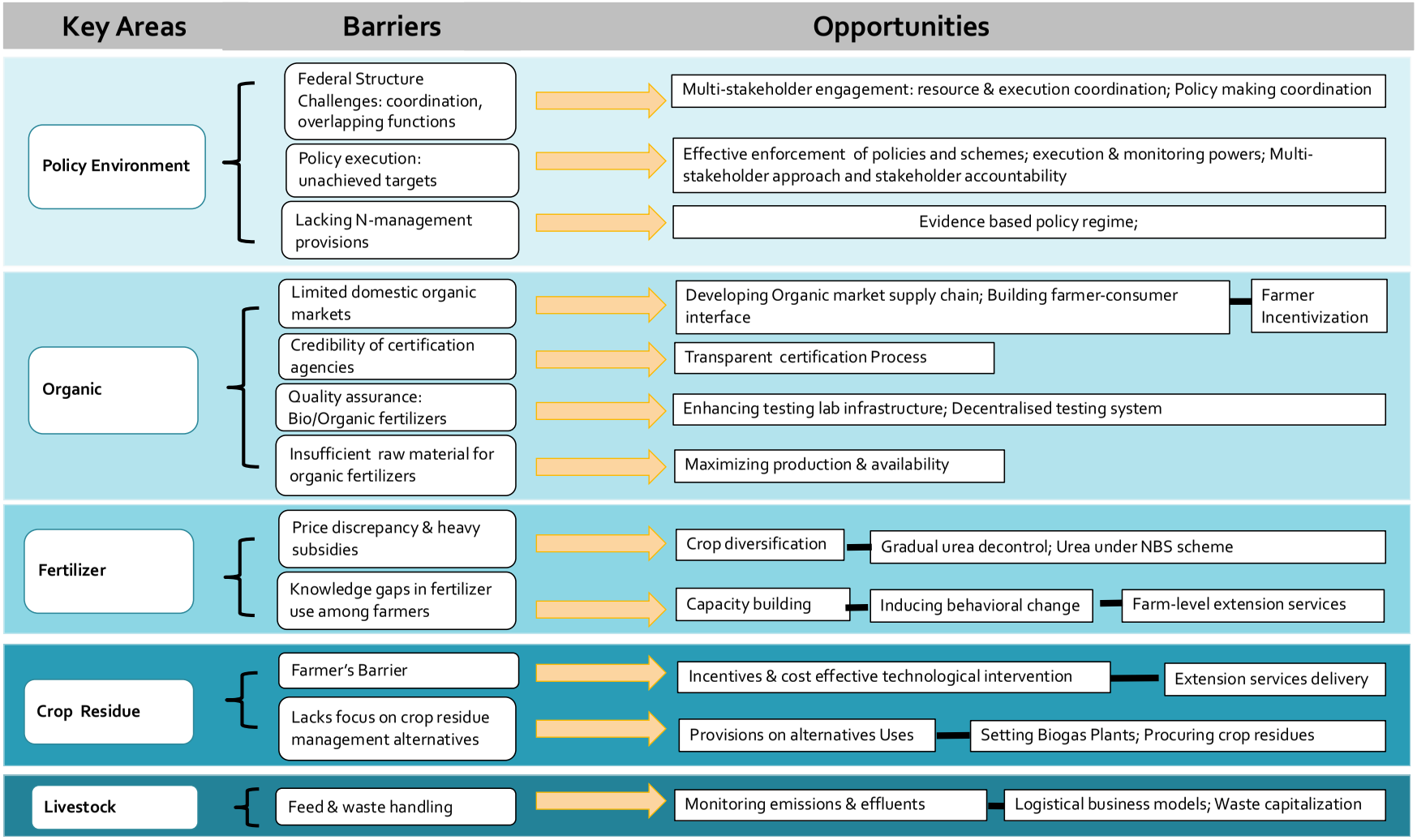


Figure 21: Barriers and respective opportunities across key decision areas for N management in agriculture

4.5.5 Policy Environment

The policy environment encompasses all facets of policy-making- nature of governance (federal/quasi-federal structure, for instance), and the need for convergence and coordination among government ministries or departments to address the nitrogen issue across the sub-sectors- fertiliser, organic, crop residue and livestock. The degree of coordination, execution efficacy and transparency in the policy-making process are factors that will have a significant impact on the development of a nitrogen regime.

4.5.5.1 Policy Environment: Barriers

Government Department fragmentation: During the semi-structured interview, the judiciary expert reflected on the existing fragmentation within various government ministries, departments, and agencies. He expressed concern over the lack of an effective structure to bring central and state policymakers together to debate issues, develop solutions, and track the progress of various initiatives.

"The problem which we are facing is that the government has different departments, these departments have different objectives… It is a well-known fact that excessive use of fertiliser, chemical fertiliser, is affecting the soil, groundwater, and air. But, then one wing of the government says we can't compromise on this aspect, because we must take care of the food production… that is our priority".

- Green Tribunal Justice during stakeholder interview

The literature also highlights parallel evidence on the issue that each government department in the agriculture sector has its own mission and objectives to achieve. Often, these objectives create conflicting interests over issues concerning environmental protection versus sector growth. Hence, there is a substantial possibility of fragmentation, overlapping, and unclear responsibility attribution (Review of Agriculture Policies in India, 2018) among the government stakeholders. This fragmented approach further leads to an inefficient implementation and execution of policies and schemes. The interview discussion with the stakeholders (researchers, NGOs, judiciary, and farmers) reflected the inadequacy of implementing measures concerning MSP and subsidies, crop diversifications, livestock feed, and waste handling. The gaps in the execution of these policy instruments are highlighted by the unachieved targets with reference to crop residue management, the soil health card scheme, and the government's delayed responses to the NGT's recommendations concerning environmental implications.

Limited Integration of N management provisions: The literature review and expert viewpoints reflected the inadequacy of the existing policy regime to focus on N management. Moreover, the major concerns are governed by an emphasis on carbon issues, and perhaps, considering the lack of efforts in this area, one of the research scientists interviewed expressed, *"If we do not manage the N well, it would be much worse than the carbon scenario"*. The content analysis of policies confirmed consistent emphasis on food sufficiency, fertiliser availability and subsidies, reducing dependency on imports, etc. From the policies under analysis, only two policies explicitly mentioned 'N Use Efficiency' in their text, including the Guidelines for 'Production and Use of Customised Fertilisers', and 'National Mission for Sustainable Agriculture'. Even where regulation exists, either there is an enforcement gap, or it does not seriously consider encouraging nutrient management, organic farming, balanced chemical fertiliser use, boosting compost, biofertilisers and livestock waste under agriculture use and adequate funding support, etc. In

addition, the content analysis findings particularly point out the lack of policy focus on sustainable N waste management in the livestock sector. N gets side-lined.

4.5.5.2 Policy Environment: Opportunities

Effective Federal Policy Regime: An efficient and coordinated mechanism among government agencies (across the centre and state) is crucial for complementing policy, technical, and behavioural reforms across society. For managing the N problem, inter-ministerial coordinated efforts are deemed crucial for a multi-sectoral emission reduction approach (Raghuram et al., 2021). Further, multi-stakeholder engagement becomes imperative to successfully harness intellectual, financial, and infrastructural resources with governments, the UN, civil society, and the fertiliser industry (Raghuram et al., 2020). As emerging from the farmer interviews, their voices are unheard even where farm-level issues are discussed, and they can also offer solutions to the problem- or a better understanding. Thus, for a robust policy process, a consultative mechanism is imperative. This will help in better execution and monitoring of the policy and will instil greater accountability among stakeholders.

Research and Evidence-Based Nitrogen Policy Formulation: Inculcating an evidence-based policy regime would require researchers to inform policymakers on effective N management measures via rigorous research. Since current policies on N are neither uniform nor adequate (Raghuram et al., 2020), N policy reforms could be encouraged at multiple levels- first at the National level to create a compelling policy landscape at the macro scale, which could then encourage state-level action. Meanwhile, the existing agricultural policy framework should seek revisions based on the urgency of the nitrogen scenarios by clearly identifying agriculture as a major source of N pollution. Along with researchers' responsiveness, the government must swiftly accept recommendations for policy making, implementing, and enforcing them. Interviewed farmers also supported greater engagement and evidence-based policies that could help in a smooth transition. Appropriate funding structures for research institutions would be required for robust and scientifically backed recommendations. Therefore, the government must expedite its efforts to formulate research-based N policy measures to embrace efficiency in N management across the agriculture sector.

5. Conclusion

Over the last half-century, the issue of excess N seems to have spread from isolated regions to the whole world. Researchers have been showing that 'too little nitrogen' is just as big of a concern as 'too much nitrogen' and have thus focused on advocating for 'just enough nitrogen' (Sutton et al., 2020). In the agriculture sector, nitrogen is essential for food production, but its overuse pollutes the air and water with ammonia, nitrous oxide, nitrites, and nitrates. In India’s case, the agriculture policies have concentrated on "farmers" and “changing farmer behaviour’ rather than the entire agriculture food supply chain," which may explain the nitrogen policy vacuum. An agriculture food supply chain is a useful tool for tracing the many hands that go into feeding the world, from manufacturing nitrogenous fertilisers to harvesting crops for human consumption. The research uses India's agricultural sector for country-level analysis. This study examines how stakeholder decisions in the agriculture food supply chain affect N management policies.

India’s fertiliser use is predicted to double by 2050; hence it needs more robust nitrogen management policies. The national-level policy analysis reveals that food security and environmental sustainability remain linked problems. In recent years, policies have shifted focus

from self-sufficiency to faster, more inclusive, and sustainable agriculture. However, key decision areas requiring nitrogen management lack policy attention. Concerns like nutrient management, organic farming, balanced chemical fertiliser use, composting, biofertilisers, livestock waste in agriculture, and crop residue burning lack policy impetus.

Policy measures that support optimal nutrient application are required considering the barriers, which include farmers' lack of technical knowledge of nitrogen usage efficiency, price variations, and heavy subsidies. Conversely, the opportunities lie in enhancing access to extension services, promoting crop diversity, and adopting a rational and well-rounded approach to subsidised fertiliser. Therefore, it may be helpful to develop a stable policy environment in the fertiliser industry to promote effective and sustainable growth. The present policy gaps in the industry also contribute to farmers' reluctance to adopt organic methods. There are several challenges that organic farmers face, including a dearth of established markets, low-grade organic supplies, and a complex and expensive certification procedure. Long-lasting, sustainable changes will need substantial government support for organic practices via means such as functional organic markets, infrastructural facilities, certifying organisations, availability of quality inputs, and awareness-raising campaigns. Similarly, when we look at the crop-residue burning concerns in the sector, our analysis reveals the underlying policy implementation gaps, despite many government efforts to prevent agricultural residue burning by farmers. The government, using a nexus approach, may overcome residue management constraints by coming up with incentive or subsidy-based models for farmers, capitalising on residue waste, building capacity, and providing technology solutions at accessible rates. The livestock sector has been highlighted as one that does not provide substantial attention to the challenges of N management, mostly because of the industry's concentration on expanding dairy output without considering the waste and feed handling that are discharged throughout the process. To address the waste management gap in the cattle industry, there is a need to enforce laws and regulations, work towards a decentralised system to monitor pollution, fund research into alternative waste utilisation techniques, and approach capitalising waste via business models in a logical manner.

Besides the substantive policy caveats, there are challenges in the policy environment. Federal and state-level officials are not regularly invited to discuss problems, provide solutions, and monitor implementation. As a result, there is a high risk of derangement, duplication, and ambiguity in allocating responsibilities among government stakeholders. Policy, technological, and behavioural improvements need a well-coordinated governance framework. Multi-stakeholder engagement is necessary to effectively use intellectual, financial, and infrastructural resources due to the many levels at which N concerns must be identified and resolved. As nitrogen pollution in South Asian nations comes from multiple sectors (agricultural, energy, transport, and industry) overseen by several ministries and departments, designating nodal ministries for each nitrogen pollutant might assist in minimising inter-ministerial coordination issues.

Overall, our policy and stakeholder research findings emphasise the need for stakeholder engagement with governments, research bodies, international agencies, civil society, and the industry to regulate N concerns through scientific partnerships, research dissemination, and policy communications. Since none of the nations in the South Asian region have consistent or sufficient N policies now, integration of a robust N policy regime must be supported at the macro level (Yang et al., 2022). Meanwhile, the sector's seriousness towards sustainable N management must be reflected in the revision of the agricultural policy framework with concerted multi-stakeholder efforts.

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List of Annexure

- Annexure 1. Codebook for Content Analysis of Policy Documents
- Annexure 2. List of Shortlisted National Agri-Sector Policies
- Annexure 3. Details of stakeholder interviews conducted to understand nitrogen management in the agriculture sector

Annexure 1. Codebook for Content Analysis of Policy Documents				
S. No	**NVivo Codes**	**Description**	**Coding Purpose**	**Word Searches**
1	Nitrogen Use Efficiency	Relationship b/w N input compared to N output, N uptake efficiency of crops	1. To identify whether policies are emphasising on mechanisms to maximise NUE in crops as researchers have pointed out the importance of maintaining the NUE or applying 'just enough N' for managing N pollution.	"Nitrogen use efficiency" OR "NUE" OR "fertiliser application" OR "fertiliser use" OR "nitrogen loss" OR "fertiliser requirement assessment" OR "nitrogen emissions" OR "site specific nutrient management"
2	Fertiliser Type	Natural/ chemical substances applied to improve crop growth and production	1. Policy shifts from Nitrogenous to Non-nitrogenous fertilisers/sustainable alternatives- Trend analysis	"fertiliser" OR "synthetic" OR "fertiliser" OR "Nitrogenous fertiliser" OR "non-nitrogenous fertiliser" OR "ammonia" OR "NPK" OR "bio-fertiliser" OR "nano-fertiliser" OR " manure" OR "agriculture input" OR "urea" OR "neem coated urea" OR "customised fertilisers" OR "indigenous urea" OR "fortified urea" OR "coated urea" OR "slow-release fertiliser"
3	Fertiliser Subsidy	Government incentive leading to fall in price of subsidised product like N fertilisers	1. Identifying the fertiliser subsidies pattern/trends in agriculture policies (which policies emphasise more on subsidising nitrogenous fertilisers, which ones promote use of non-nitrogenous/ organic fertilisers through subsidies?) 2. Also look at fertiliser pricing trends.	"subsidies" OR "fertiliser regulation" OR "fertiliser distribution" OR "market fluctuation" OR "pricing" OR "fertiliser production" OR "fertiliser availability" OR "excessive use" OR "MRP" OR "market-determined rates" OR "demand-and-supply rate"
4	Organic Farming	agricultural system that uses ecologically based pest controls and biological fertilisers	1. Which Policies promote the organic shift in the use of fertilisers? 2. What have been the drivers of this policy shift? 3. What incentives are used for facilitating the organic shift?	"organic farming" OR "organic input" OR "manure management" OR "soil health assessment" OR "limited N use" OR "N use regulation" OR "Fertiliser regulation" OR "Biological N harvesting "
5	Crop Residue	Materials left in agricultural field post-harvest	1. How the reasons and intervention strategies have changed over a period. 2.Analyse the policy attempts to curb crop residue burning	"crop residue" OR "crop residue management" OR "crop burning" OR "stubble burning" OR "stubble clearing " OR "black carbon" OR "smog" OR "post-harvest" OR "straw burning" OR "agricultural burning" OR "crop by-product"

6	Livestock feed and waste management	Livestock supply chains are major source of N emissions, nitrous oxide source	1. Whether livestock management policies factor in the contribution of the livestock sector in N pollution? 2. How Policies are trying to manage N pollution from livestock waste?	"Animal husbandry" OR "dairy" OR "excessive dairy residue" OR "GHG emissions" OR "feed management" OR "waste management" OR "manure"
	Agriculture-N management stakeholders	Who is affected by the decisions and actions they take, and who has the power to influence their outcome	1. Which policies consider the agriculture sector stakeholders to be important in the policy execution and performance? (Importance of stakeholders) 2. Which stakeholders emerge important in policy documents? (will first consider the word frequencies to identify the overall pattern, then do an interpretative analysis to understand their roles and interests) 3. Which stakeholders bear more influence on the policy process? 4. How the policy community (actors that are mentioned in the policies) change over time. How do their roles and diversity of actors change? 5. To map the strategy change over a period of time- how they have problematised the issue and dealt with solutions?	Government Body- "advisor" OR "Government" OR "Government Body" OR "Government officials" OR "Government agencies" OR "Certification agencies" OR "Government departments" OR "departments" OR "state government" OR "Ministries"
				Industry and Market Actors- "Industry" OR "Fertiliser industry" OR "Fertiliser industry" OR "Private Sector" "Market channels" OR "Market actors" OR "Dealers" OR "Retailers" OR "Manufacturers" OR "Input dealers" OR "Middlemen" OR "Financial Organisation" OR "traders" OR "Processors" OR "Certification Agencies"
				"Civil Society- farmers" OR " cultivators" OR "producers" OR "livestock farmers" OR "Farmer Associations" OR "FPOs" OR "Civil Society" OR "CSOs" OR "Non-govt organisations" OR "NGOs" OR "Media"
				"Research Bodies- "Researchers" OR "Research Institutes" OR "Research Organisations" OR "Extension Services" OR "Krishi Vigyan Kendra" OR "KVKs" OR "NARS" OR "National Agriculture Research System"
				"International Organisations" OR "International Bodies"

Annexure 2. List of Shortlisted National Agri Sector Policies		
Policy Sub-sectors	Policy	Access Link
Fertiliser related reforms	FMCO: The Fertiliser (Movement Control Order 1973)	https://dag.gujarat.gov.in/images/directorofagriculture/pdf/fmco1973.pdf
	PUCF: Guidelines for Production and Use of Customized Fertilisers 2008	https://fertiliserindia.com/wp-content/uploads/2021/04/policy-on-CF.pdf
	FCO: Fertiliser (Control) Order 1985 (*Amended in 2013)	https://www.fao.org/faolex/results/details/en/c/LEX-FAOC129935/
	NUP: New Urea Policy 2015	Urea Policy (Pricing and Administration) | Department of Fertilisers
	Policy for encouraging production and availability of fortified and coated urea 2015	http://fert.nic.in/sites/default/files/What-is-new/Policy%20for%20encouraging%20production_0.pdf
Organic Farming	NPOF: National Project on Organic Farming 2010	https://agricoop.gov.in/sites/default/files/gnpof11511.pdf
	PKVY: Paramparagat Krishi Vikas Yojana 2015	Paramparagat Krishi Vikas Yojana (PKVY)
Livestock Feed and Waste Management	NLP: National Livestock Policy 2013	https://dahd.nic.in/sites/default/filess/NLP%202013%20Final11.pdf
Crop Residue Management	NPCR: National Policy for Management of Crop Residue 2014	National Policy
Broad-based Policies	NMSA: National Mission for Sustainable Agriculture 2010	https://agritech.tnau.ac.in/nmsa/pdf/National%20Mission%20For%20Sustainable%20Agriculture-DRAFT-Sept-2010.pdf
	NAP: National Agricultural Policy 2000	National Agricultural Policy | Agropedia
	NPF: National Policy for Farmers 2007	_https://ibkp.dbtindia.gov.in/DBT_Content_Test/CMS/Guidelines/20181115125145657_National-Policy-for-Farmers_2007.pdf
	DFIP: Doubling Farmers Income Policy 2017	https://ibkp.dbtindia.gov.in/DBT_Content_Test/CMS/Guidelines/20181115125438058_DOUBLING%20FARMERS%20INCOME.pdf
	RKVY: The Rashtriya Krishi Vikas Yogna or The National Agriculture Development Programme 2007	https://agricoop.gov.in/en/RashtriyaDiv
	SHCS: Soil Health Card Scheme 2015	https://www.soilhealth.dac.gov.in/Content/FAQ/FAQ_Final_English.pdf
	PMKSY: Pradhan Mantri Krishi Sinchai Yojana 2015	Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)
	BGREI: Bringing Green Revolution in Eastern India 2010	https://rkvy.nic.in/static/download/pdf/BGREIGuidlines.pdf

Annexure 3. Details of stakeholder interviews conducted to understand nitrogen management in the agriculture sector				
Stakeholder Groups	**Stakeholder Categories**	**Issues Discussed**	**Institution**	**Number of Stakeholder Interviews**
Government Bodies	Key Players	Entry points for policy shift, Fertiliser subsidies, stakeholder importance, policy challenges and solutions	Ministry of Agriculture & Farmers Welfare	(n=1)
			National Green Tribunal	(n=1)
Research Organisation	Promoters	Farming risks and preferences in sustainable shifts, policy measures, role of stakeholders, research and innovation, research organisation's roles and constraints in N management	GGS Indraprastha University	(n=1)
			KIIT University	(n=1)
			IARI	(n=1)
Industry	Promoters	Farmers' adoption rate and preferences, market strategies, fertiliser subsidies and pricing, energy efficiency in production, policy shifts required	Fertiliser Association of India	(n=1)
			Syngenta	(n=1)
Non-Government Organisations	Crowd	Fertiliser use trends, interventions, policy implementation constraints at the grassroots, stakeholder roles, challenges in building farmer capacities	Sustainable India Trust	(n=1)
			BAIF	(n=3)
Organic Farmers	Subjects	Perceptions and risks, crop residue management, enabling policy environment,	Haryana, Uttarakhand	(n=8)