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Final report

INI 2021 – 8th Global Nitrogen Conference

by:
Henning Friege
Nachhaltigkeitsberatung Dr. Friege & Partner, Voerde
Markus Geupel
Umweltbundesamt, Dessau
Stefanie Wolter
Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit, Berlin
Technical Assistance by Svenja Jürgens, David Obladen
Akademie Dr. Obladen GmbH, Berlin

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Nitrogen and the United Nations Sustainable
Development Goals

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Henning Friege
Nachhaltigkeitsberatung Dr. Friege & Partner, Voerde

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Bundesministerium für Umwelt, Naturschutz und nukleare
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Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
buergerservice@uba.de
Internet: www.umweltbundesamt.de

/umweltbundesamt.de
/umweltbundesamt

Report performed by:
N³ Nachhaltigkeitsberatung Dr. Friege & Partner (text)
Scholtenbusch 11
D-46562 Voerde

Akademie Dr. Obladen (technical support)
Katharinenstr. 8
D-10711 Berlin

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Abstract: INI 2021 – 8th Global Nitrogen Conference

This document contains abstracts of presentations and results from the 8th Global Nitrogen Conference, which took place from 30 May to 3 June 2021. The International Nitrogen Initiative (INI) organizes conferences at intervals of three to four years, at which the latest scientific findings regarding the sources of reactive nitrogen compounds, the damage they cause to health and the environment, methods for needs-oriented nitrogen fertilization, technical innovations and the development of regional and global pollution are discussed. The 8th Global Nitrogen Conference was hosted by the German Environment Agency. Due to the coronavirus pandemic, the conference was postponed from 2020 to 2021 and held in a virtual format, but with technical, organizational and content-related support from Berlin. It mirrored the connections between nitrogen and the global environmental goals of the United Nations (Sustainable Development Goals, SDGs) and was therefore structured according to the following topics: Nutrition and lifestyles (SDGs 2, 12 and 11), agriculture, food and animal feed (SDGs 2 and 3), ensuring health, clean water and clean air (SDGs 3, 6 and 11), combating threats to biodiversity (SDGs 15 and 14), observing global challenges, nitrogen fluxes and interactions between different drivers of pollution (SDG 13), closing the N cycle (SDG 14), innovations for sustainable N management (SDG 9), integrated science and policy approaches, public awareness, communication (SDGs 4, 8 and 17). Accordingly, the "Berlin Declaration" adopted at the end of the conference incorporates current environmental policy discussions and objectives at global level and formulates guidelines for future political action at international and national level on the basis of the new scientific findings.

Kurzfassung

Das vorliegende Dokument beinhaltet Kurzfassungen von Vorträgen und Ergebnissen anlässlich der 8th Global Nitrogen Conference, die vom 30. Mai bis zum 3. Juni 2021 stattfand. Die International Nitrogen Initiative (INI) veranstaltet in Abständen von drei bis vier Jahren Konferenzen, bei denen der jeweils neueste Stand der wissenschaftlichen Erkenntnisse zu den Quellen reaktiver Stickstoff-Verbindungen, dadurch verursachte Gesundheits- und Umweltschäden, Methoden zu einer bedarfsgerechten Stickstoff-Düngung, technische Innovationen und die Entwicklung der regionalen und globalen Belastung diskutiert werden. Gastgeber der 8th Global Nitrogen Conference war das Umweltbundesamt. Wegen der Covid19-Pandemie wurde die Konferenz von 2020 auf 2021 verschoben und virtuell durchgeführt, allerdings von Berlin aus inhaltlich, technisch und organisatorisch betreut. Die Konferenz wurde an den Zusammenhängen zwischen Stickstoff und den globalen Umweltzielen der Vereinten Nationen (Sustainable Development Goals, SDGs) ausgerichtet. Die Gliederung umfasste daher die Themen Ernährung und Lebensstile (SDGs 2, 12 und 11), Landwirtschaft, Nahrungs- und Futtermittel (SDGs 2 und 3), Sicherstellung von Gesundheit, sauberem Wasser und reiner Luft (SDGs 3, 6 und 11), Bekämpfung von Gefahren für die Biodiversität (SDGs 15 und 14), Beobachtung globaler Entwicklungen, Stickstoff-Flüssen sowie Wechselwirkungen zwischen verschiedenen Belastungsursachen (SDG 13), Schließung von Stickstoff-Kreisläufen: Innovationen für ein nachhaltiges Management von Stickstoffverbindungen (SDG 9), Integration wissenschaftlicher Ansätze in die Politik, öffentliches Bewusstsein, Kommunikation (SDGs 4, 8 und 17). Konsequenterweise nimmt die zum Abschluss der Konferenz verabschiedete „Berlin Declaration" aktuelle umweltpolitische Diskussionen und Ziele auf globaler Ebene auf und formuliert auf Basis der neuen wissenschaftlichen Erkenntnisse Vorgaben für das zukünftige politische Handeln auf internationaler und nationaler Ebene.

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List of abbreviations

AOB	Ammonia oxidizing bacteria
AOA	Ammonia oxidizing archaea
CLRTAP	Convention on long-range transboundary air pollution
C	Carbon
CO_2	Carbon dioxide
COP	Conference of the Parties
CrIS satellite	Cross-track Infrared Sounder satellite
DMPP	3,4-dimethylpyrazole phosphate
ERC	Environmental Research Communications
ERL	Environmental Research Letters
EUNEP	EU Nitrogen Expert Panel
FAO	Food and Agriculture Organisation of the United Stations
HPLC	High pressure liquid chromatography
IASI satellite	Infrared Atmospheric Sounding Interferometer satellite
INI	International Nitrogen Initiative
INMS	International Nitrogen Management System
IPCC	International Panel on Climate Change
IUCN	International Union for Conservation of Nature
N	Nitrogen
N_2O	Nitrous Oxide
N_r	Reactive nitrogen species
NH_3	Ammonia
NO_x	Nitrogen Oxides
NUE	Nitrogen Use efficiency
LCA	Life Cycle Assessment, Life Cycle Analysis
O	Oxygen
OECD	Organisation for Economic Co-operation and Development
P	Phosphorous
PAS	Programmatic Approach on Nitrogen
PM	Particulate matter
PNB	Partial N balance
PU	Prilled urea
S	Sulphur
SDG	Sustainable Development Goals
TiO_2	Titanium Dioxide

UDP	Urea deep placement
UNEA	United Nations Environment Assembly
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
VNIR	Visible and near infrared

1 Zusammenfassung

1.1 Eine Konferenz unter COVID-19

Reaktive Stickstoffverbindungen sind angesichts einer wachsenden Weltbevölkerung eine Schlüsselressource für die Nahrungsmittelproduktion. Gleichzeitig führen menschliche Aktivitäten durch verschiedene Prozesse zu Verlusten von reaktivem Stickstoff in alle Umweltmedien. Die dadurch gesteigerte Verfügbarkeit von reaktivem Stickstoff in der Biosphäre hat vielfältige Auswirkungen auf die Umwelt, die menschliche Gesundheit, das Klima und die Biodiversität.

Der Druck auf die Ressourcen und die Ökologie des Planeten nimmt stetig zu. Die Menge an reaktiven Stickstoffverbindungen, die global gesehen in die Umwelt emittiert wird, ist gemessen an der „Planetaren Grenze für Stickstoff" deutlich zu hoch. Zudem sind die meisten UN-Nachhaltigkeitsziele (Sustainable Development Goals, SDGs) eng mit dem Stickstoffkreislauf verknüpft: Viele SDGs sind nur erreichbar durch einen bewussteren und effizienteren Umgang mit Stickstoff, zum Beispiel einer Steigerung der Effizienz der Stickstoffnutzung in der Lebensmittelproduktion und einer Verringerung unerwünschter Stickstoffemissionen in die Biosphäre. Dies unterstreicht, wie wichtig neue Lösungen für dieses komplexe Problem sind; Lösungen, die zudem zu den Rahmenbedingungen und der Problemlage in der jeweiligen Region passen müssen. Auch die Resolution der vierten Umwelthauptversammlung der Vereinten Nationen (United Nations Environment Assembly, UNEA-4) mit dem Titel „Sustainable Nitrogen Management" (Nachhaltiges Stickstoffmanagement)[1] betont die vielfältigen Bedrohungen der Umweltverschmutzung durch anthropogenen, reaktiven Stickstoff mit negativen Auswirkungen auf die Luftqualität sowie auf die terrestrische, Süßwasser- und Meeresumwelt. Der Resolutionstext ruft dazu auf, effektive Maßnahmen zur Zielerreichung der SDGs zu ergreifen.

Die 8. Konferenz der International Nitrogen Initiative (INI2021) widmete sich diesem Ziel: Wissenschaftler aus aller Welt zusammenzuführen, die sich mit reaktiven Stickstoffverbindungen in Landwirtschaft, Industrie, Verkehr, Boden, Wasser und Luft befassen. Ziel der Konferenz war es, Ergebnisse, Ideen und Visionen auszutauschen, um das Management von reaktivem Stickstoff so zu verbessern, dass Hunger und Armut weiter reduziert und gleichzeitig weitere Gefahren für die menschliche Gesundheit, die Biodiversität sowie für Wasser, Luft und Boden vermieden werden können. Gleichzeitig bot die Konferenz Gelegenheit, Wissenschaftler mit wichtigen politischen Entscheidungsträgern und relevanten Interessengruppen in Austausch zu bringen. Das Abschlussdokument der Konferenz, die Berlin Declaration, fußt auf den neuesten wissenschaftlichen Erkenntnissen und will weitergehende politische Maßnahmen für ein wirksames integriertes Stickstoffmanagement anregen.

1.2 Ausrichtung der Konferenz durch Deutschland

Konferenzen der International Nitrogen Initiative (INI) finden etwa alle drei Jahre alternierend auf verschiedenen Kontinenten statt. Bisherige Ausrichter waren Institutionen in den Niederlanden (1998), den USA (2001), China (2003), Brasilien (2007), Indien (2010), Uganda (2013) sowie Australien (2016). Nach der ersten Konferenz in den Niederlanden 1998 wurde die INI2021 wieder von Europa aus organisiert. Deutschland war erstmalig Gastgeber der INI-Konferenzreihe. Das ist von besonderer Bedeutung, da die Wissenschaftler Fritz Haber und Carl Bosch in Deutschland vor rund 100 Jahren die industrielle Ammoniakfixierung erfunden haben; ein Prozess, der heutzutage zum einen die Ernährung von gut der Hälfte der Weltbevölkerung sicherstellt, zum anderen jedoch auch die Hauptquelle des reaktiven Stickstoffs ist, der in die Biosphäre entweicht.

[1] https://wedocs.unep.org/bitstream/handle/20.500.11822/28478/English.pdf?sequence=3&isAllowed=y

Da auch in Deutschland viele Umweltziele auf Grund zu hoher Stickstoffbelastung der Biosphäre nicht erreicht werden können, war die Ausrichtung der globalen Konferenz für die Umweltverwaltung von Deutschland von großer Bedeutung. Im Jahr 2015 hat das Bundesumweltministerium begonnen, die Aktivitäten zur integrierten Stickstoffminderung in Deutschland zu koordinieren. Der globale Austausch zu neusten wissenschaftlichen Erkenntnissen im Bereich Stickstoffminderung im Zuge der INI-Konferenz wurde daher als wichtiger Baustein für die integrierte Stickstoffpolitik in Deutschland erkannt. Darüber hinaus war es dem Umweltministerium und dem Umweltbundesamt ein Anliegen, eigene Erfahrungen im Bereich integrierter Stickstoffminderung einem internationalen Publikum in Berlin weiterzugeben. Nach der Stickstoffkonferenz in Australien reichte daher das Umweltbundesamt als wissenschaftliche Behörde im Geschäftsbereich des Umweltministeriums die Bewerbung zur Ausrichtung der Konferenz in Berlin bei der INI ein. Diese wurde am 4. Juli 2017 positiv beschieden.

Mit der Übernahme der Gastgeberrolle durch das Umweltbundesamt (UBA) wird der Stellenwert dieses Umweltproblems auf nationaler Ebene hervorgehoben. Zudem wurde die Konferenz erstmalig von einem nationalen Ministerium mitausgerichtet.

1.3 Organisationsprozess

Zu Beginn des Jahres 2018 startete das Umweltbundesamt den Aufbau eines Konferenz-Sekretariats. Dazu konnten Projektgelder des Bundesumweltministeriums gesichert werden und ein Projekt zur Vorbereitung, Durchführung und Nachbereitung ausgeschrieben werden. Als Projektpartner konnten die Veranstaltungsagentur Akademie Dr. Obladen (ADO) sowie N^3 Nachhaltigkeitsberatung gewonnen werden. Zum Aufgabenspektrum des Konferenz-Sekretariats gehörten u. a. die Auswahl eines Veranstaltungsorts in Berlin, die Gestaltung der erforderlichen Kommunikationsmedien, die Kommunikation mit Teilnehmenden, die Durchführung des Finanzmanagements, die Koordinierung der wissenschaftlichen Programmgestaltung, die Planung eines Rahmenprogramms und der Support von Teilnehmenden und eingeladenen HauptrednerInnen. Insgesamt wurden in etwa zwei Jahren u. a. rund 30 Newsletter verschickt.

In allen organisatorisch bedeutsamen Aspekten stand das Konferenz-Sekretariat stets in engem Kontakt zum INI-Steuerungsgremium.

1.4 INI2021-Komitees

Um das Konferenz-Sekretariat zu unterstützen, wurden verschiedene Komitees mit spezifischer Beratungsfunktion eingerichtet:

- Zwei Beratungskomitees: ein lokal besetztes und ein internationales. In den Beratungskomitees arbeiteten elf bzw. 16 renommierte FachexpertInnen aus unterschiedlichen stickstoffrelevanten Fachdisziplinen. Die beiden Beiräte unterstützten das Konferenz-Sekretariat mit Vorschlägen und wissenschaftlichen Empfehlungen für die Programmstruktur, Programmschwerpunkte, Sondersitzungen und mögliche HauptrednerInnen. In enger Zusammenarbeit entschieden alle drei Gruppen gemeinsam über das endgültige Konferenzprogramm. Die Beiräte halfen als wichtige Multiplikatoren zudem, die zentralen Informationen zur Konferenz in ihren Netzwerken zu verbreiten.
- Übergreifend und zusammengesetzt aus internationalen FachexpertInnen wurde zusätzlich ein Wissenschaftliches Komitee eingerichtet. Dieses war für die fachliche Prüfung der eingereichten Beiträge und die Entscheidung über deren Annahme zuständig. Es setzte sich zusammen aus zahlreichen Mitgliedern des Lokalen und des Internationalen Komitees, des Konferenz-Sekretariats, ergänzt um weitere ExpertInnen

aus Wissenschaft, Verwaltung, wissenschaftlichen Verbänden und Industrie. Dieses Komitee hatte insgesamt 50 Mitwirkende.

Die Besetzung der Komitees ist unter dem folgenden Link wiedergegeben: https://ini2021.com/information/#committees

1.5 COVID-19-Auswirkungen

Ursprünglich war geplant, die Konferenz Anfang Mai 2020 durchzuführen. Zwei Jahre intensive Planung und Vorbereitung waren dem vorausgegangen. Aufgrund der sich Anfang 2020 verschärfenden COVID19-Pandemie wurde zehn Wochen vor Veranstaltungsbeginn, im März 2020, die Entscheidung getroffen, die INI2020 zu verschieben; Großveranstaltungen waren nicht mehr möglich. Zu diesem Zeitpunkt galten nahezu 250 Vorträge und 150 Posterbeiträge als bestätigt, das wissenschaftliche Programm war bereits veröffentlicht und rund 300 Teilnehmende hatten sich registriert. Die Rückabwicklung der zu diesem späten Zeitpunkt annähernd vollständig durchgeplanten fünftägigen Konferenz war sowohl für die Ausrichter als auch die zahlreichen angemeldeten Teilnehmenden aufwendig. In den folgenden Monaten erschwerte die ungewisse Pandemieprognose die weitere Planung. Es wurde anvisiert, die INI2021 zunächst um ein halbes dann um ein volles Jahr zu verschieben, in der Hoffnung auf eine Besserung der Pandemielage.

Am 4. Mai 2020, dem Tag, der ursprünglich für die Eröffnung der Konferenz vorgesehen gewesen war, wurde ein kurzfristig organisiertes virtuelles Event durchgeführt. Dies sollte die Bedeutung des Stickstoff-Themas unterstreichen und ein Vorgeschmack auf die verschobene Konferenz bieten. Im Rahmen des zweistündigen Zoom-Webinars drückte Prof. Dr. Dirk Messner, Präsident des Umweltbundesamt und damit Gastgeber, in einer Videobotschaft sein Bedauern über die kurzfristige Absage der Konferenz und seine Zuversicht aus, die Veranstaltung zu einem späteren Zeitpunkt in Berlin nachholen zu können. Das Webinar, an dem rund 300 WissenschaftlerInnen weltweit teilnahmen, wurde von den INI-Vorsitzenden Ass. Prof. Dr. David Kanter und Prof. Dr. Nandula Raghuram geleitet. Es lässt sich unter https://ini2021.com/virtual-event-2020/ in voller Länge anschauen.

Schließlich wurde geplant, die Konferenz vom 31. Mai   3. Juni 2021 nachzuholen. Damit verbunden waren die Verlängerung und Aufstockung des Begleitprojekts. Zunächst wurde davon ausgegangen, dass die Konferenz im hybriden Format durchgeführt werden könnte. Im Oktober 2020 wurde jedoch auf ein vollständig virtuelles Format umgestellt: Es war zu unsicher, ob bis zum Konferenzbeginn wieder größere Präsenzveranstaltungen möglich sein würden. Außerdem hätte das Hybrid-Format eine erhebliche Kostensteigerung bedeutet, da neben den Räumlichkeiten im Tagungshotel zusätzlich noch IT- und Übertragungstechnik zu finanzieren gewesen wäre. Diese Umorganisation mit deutlichen Programmanpassungen, logistischen Modifikationen (u. a. Vertragsauflösung mit dem Veranstaltungsort, Verträge mit einer virtuellen Konferenzplattform, Rückerstattung gezahlter Teilnehmerbeiträge) war enorm aufwendig. Auch das wissenschaftliche Programm musste überarbeitet werden, da diverse für 2020 in Berlin angemeldete Poster- oder Redebeiträge für die verschobene Konferenz in 2021 zurückgezogen wurden bzw. nicht mehr verfügbar waren.

Alles in allem wurde die 8. Globale Stickstoffkonferenz unter den unvorhergesehenen Pandemiebedingungen zwei Mal geplant: Zum einen als Präsenzveranstaltung und zum anderen als rein virtuelle Veranstaltung.

1.6 Wissenschaftliches Programm

Das wissenschaftliche Programm der Konferenz orientierte sich an der Überschrift „Stickstoff und die Nachhaltigkeitsziele der Vereinten Nationen“ und gliederte sich entlang acht

Themenblöcken mit insgesamt 15 Unterthemen (https://ini2021.com/program/#scientific-program). Die acht übergeordneten Themenblöcke waren die Bereiche Ernährung und Lebensstile (1), Landwirtschaft und Nahrungsmittelsicherheit (2), Gesundheit, saubere Luft, Städte und Trinkwasser (3), Bekämpfung von Risken für die Biologische Vielfalt (4), Beobachtung von globalen Herausforderungen, Stickstoffflüssen und Querverbindungen zwischen Verursachern und Belastungen (5), Innovative Lösungen für nachhaltiges Stickstoffmanagement (6), Integration von wissenschaftlichen und politischen Optionen zur Sensibilisierung von Gesellschaft und Öffentlichkeit (7) sowie sogenannte Special Sessions (8). Teil des letzten Bereichs waren die drei Sondersessions (Special Sessions) zu den Themen „Nitrogen Use Efficiency and Sustainable Nutrient Management“, „Stickstoff-Fußabdrücke“ und „Stickstoff in Wäldern“, die im Vorbereitungsprozess bei den Organisatoren zusätzlich angemeldet und realisiert werden konnten. Die hier vorliegende Dokumentation der Konferenz ist anhand dieser acht Themenblöcke gegliedert.

Zwölf Monate vor der ursprünglich geplanten Konferenz wurde im Mai 2019 die Homepage der Konferenz https://www.ini2020.com freigeschaltet, zusammen mit der Ankündigung, dass wissenschaftliche Beiträge zu acht Hauptthemen und 15 Unterthemen eingereicht werden können. Bis zum Fristablauf am 30. September 2019 erreichten das Konferenz-Sekretariat über die elektronische Plattform, die für den Call-for-Papers genutzt wurde, rund 440 wissenschaftliche Beiträge aus 33 Ländern. Alle Abstracts wurden im Auswahlprozess von je zwei FachexpertInnen des Wissenschaftlichen Komitees begutachtet. Außerdem unterstützte das Wissenschaftliche Komitee das Konferenz-Sekretariat bei der thematischen Sortierung der Vorträge in die Programmstruktur und bei der Entscheidung, ob ein Beitrag als Poster oder Vortrag angenommen werden sollte. Insgesamt wurden auf diese Weise 248 Bewerbungen als Vortrag und 149 als Poster zugelassen sowie 41 Einreichungen abgelehnt.

Für die virtuelle Konferenz im Jahr 2021 wurde kein neuer Call-for-Papers eröffnet. Alle WissenschaftlerInnen, die für 2020 mit Vortrag oder Poster eingeladen worden waren, wurden gefragt, ob sie ihre Beiträge aufrecht halten wollten. Im Ergebnis dieser Abfrage wurden rund 100 Beiträge zurückgezogen. Da auch einige wenige Beiträge nach Prüfung zusätzlich aufgenommen wurden, setzte sich das Programm für die virtuelle Konferenz im Endeffekt aus 191 Vorträgen und 91 Postern zusammen. Insgesamt konnten demnach, verursacht durch die Corona-Krise, rund ein Viertel der ursprünglich für 2020 angemeldeten Beiträge nicht gezeigt werden. Die 191 Fachvorträge wurden den 15 Unterthemen so zugeordnet, dass insgesamt 36 parallele Fachsessions gebildet wurden.

40 Beiträge, die im Review-Prozess die besten Bewertungen bekommen hatten, wurden eingeladen, ihre Forschungsergebnisse in einer Spezialausgabe der wissenschaftlichen Zeitschriften Environmental Research Communication and Environmental Research Letters zu veröffentlichen. Im Open Access Portal dieser Zeitschriften sind mittlerweile über 20 herausragende Paper der Konferenz veröffentlicht (https://iopscience.iop.org/journal/1748-9326/page/Focus_on_Reactive_Nitrogen).

1.7 Keynote Speakers

Zusammen mit dem Lokalen und dem Internationalen Beratungskomitee wurde im Vorfeld der Konferenz eine Vorschlagsliste für geeignete HauptrednerInnen zusammengestellt. Ziel war es, für die 15 Unterthemen renommierte WissenschaftlerInnen zu gewinnen, die einen Keynote-Vortrag halten. Bei der Zusammensetzung der eingeladenen RednerInnen wurde größtmöglicher Wert auf Ausgewogenheit gelegt. So gelang es ein Feld von HauptrednerInnen aufzustellen, dass sich annähernd paritätisch aus weiblichen und männlichen VertreterInnen sowie RednerInnen aus allen Kontinenten zusammensetzte.

Für Statements bei der Eröffnungssession wurden hochrangige politische VertreterInnen gewonnen: Von UN-Konventionen mit Bezug zum Stickstoffthema, vom SDG Center for Africa sowie vom Gastgeberkontinent Europa, vertreten durch eine Videobotschaft des EU-Kommissars für Umwelt, Meere und Fischerei Virginijus Sinkevičius (https://clous.uba.de/index.php/s/uj0e7OX8wYAI4hi) und das Gastgeberland, vertreten durch die Umweltministerin Svenja Schulze.

1.8 Vorprogramm: Stickstoff im Gastgeberland Deutschland

Im Vorfeld der Konferenz wurden die Teilnehmenden mit verschiedenen Kurzbeiträgen aus dem Gastgeberland Deutschland über die nationale Stickstoffproblematik und diesbezügliche historische und aktuelle Lösungsansätze in einem anregenden Format auf die Konferenz vorbereitet. Ursprünglich waren diese Programmpunkte für ein abendliches Side-Event zur physischen Konferenz vorgesehen gewesen. Diese Beiträge sind virtuell verfügbar und vollständig online einsehbar unter https://ini2021.com/pre-program-2021/.

1.9 Durchführung der Konferenz

Die Durchführung der Konferenz als Online-Veranstaltung infolge der Corona-Krise führte zu besonderen logistischen Herausforderungen. Durch die enormen Zeitunterschiede zwischen östlicher Hemisphäre (z. B. Japan und Neuseeland) und westlicher Hemisphäre (z. B. British Columbia oder Chile) wurde entschieden, die Konferenz jeweils nur zwischen 12 und 16 Uhr Mitteleuropäischer Sommerzeit durchzuführen. Für japanische und chinesische Teilnehmende bedeutete dies zum Beispiel, dass die Konferenz bis spät in die Nacht ging; für mexikanische und chilenische Teilnehmende, dass sehr frühes Aufstehen zur Bedingung wurde. Insgesamt stand für jeden der vier Konferenztage im Ergebnis jeweils ein Zeitfenster von vier Stunden zur Verfügung. Bei einer physischen Konferenz in Berlin hätte man mit einem täglichen Zeitfenster von etwa neun Stunden doppelt so viel Konferenzzeit zur Verfügung gehabt.

Zur Durchführung der Konferenz wurde das virtuelle System „Conference Compass“ genutzt. Dieses Online-Konferenz-System bot die Möglichkeit, alle Vorträge vorab aufzuzeichnen und anzusehen. Das Programm wurde hierdurch teilweise von der reinen Konferenz-Zeit entkoppelt und alle Keynotes und die 150 Fachvorträge konnten gehalten werden: Alle Vorträge der parallelen Fachsessions mussten von den SprecherInnen vorab aufgezeichnet und im Conference Compass gespeichert werden. Eine Woche vor dem tatsächlichen Konferenzbeginn waren alle Vorträge online und von den Teilnehmenden vorab dort anzusehen, um die Inhalte in den jeweiligen Live-Sessions diskutieren zu können.

Im vierstündigen Zeitfenster an den vier Konferenztagen wurden somit nur die Podiumsdiskussionen, die Keynote-Vorträge und die Diskussionsrunden zu den Fachsessions als Live-Programm durchgeführt. Für alle Diskussionsrunden, sowohl zu den Keynote Sessions als auch zu den parallelen Fachsessions, stand ein Pool von internationalen ExpertInnen moderierend zur Verfügung.

1.10 Abschlussdokument: Berliner Erklärung - Berlin Declaration

Das Abschlussdokument, die „Berliner Erklärung“ oder „Berlin Declaration“, wurde am letzten Tag der Konferenz, am 3. Juni 2021, verabschiedet. Der Entwurf wurde von Mitgliedern des INI-Steuerungsgremiums zusammen mit dem Konferenz-Sekretariat und mit Beiträgen des Lokalen und des Internationalen Beratungskomitees erstellt. Im Vorfeld der Konferenz wurde der Entwurf allen Teilnehmenden mit der Möglichkeit zur Kommentierung verfügbar gemacht.

Die Deklaration verdeutlicht die Abhängigkeit der SDG-Erreichung von der ungelösten Stickstoffproblematik. Sie mahnt, alle Umweltwirkungen und die versteckten Kosten hoher

Stickstoffeinträge angemessen zu berücksichtigen und darüber hinaus Zielkonflikte bei politischen Handlungsansätzen zu erkennen und zu lösen. Die Verfasser der Declaration sind sich jedoch bewusst, dass die Problemdimension hoher Stickstoffeinträge nach wie vor in der öffentlichen Wahrnehmung und im politischen Raum nicht umfänglich erkannt wird. Folglich wirbt die Deklaration für ein besseres Problembewusstsein. Die weltweit ungleiche Verteilung von Stickstoffnutzung und -verlusten wird dabei ausdrücklich betont. Zur Lösung des Umweltproblems plädiert die Berlin Declaration für verstärkte Anstrengungen zur Integration des nachhaltigen Stickstoffmanagements in umweltpolitische Bemühungen auf allen Ebenen und für ehrgeizige nationale und internationale Zielsetzungen. So verweist sie u. a. auf die UN Colombo Declaration von 2019 und deren Ziel, die Stickstoffabfälle bis 2030 zu halbieren.

Die „Berliner Erklärung“ wurde von den Vorsitzenden der INI, Prof. Dr. Nandula Raghuram und Ass. Prof. Dr. David Kanter, sowie der Bundesumweltministerin Svenja Schulze und der Vizepräsidentin des UBA, Dr. Lilian Busse, gezeichnet und wird von den Teilnehmenden der INI2021 unterstützt. Das vierseitige Dokument steht unter dem folgenden Link zum Download bereit: https://ini2021.com/berlin-declaration/.

1.11 Dokumentation der Konferenz

Die vorliegende Dokumentation ist eine Zusammenfassung aller Ergebnisse der Konferenz bzw. ermöglicht eine Verknüpfung zu den digital archivierten Ergebnissen. Im Hauptteil dieses Berichts wurden die Vorträge der Konferenz zusammengefasst, Verlinkungen zu den Abstracts und Folien gesetzt und der Inhalt aus den parallelen Diskussionsrunden wiedergegeben. Soweit möglich, wurden die Notizen und Zusammenfassungen der fachlichen Moderatoren genutzt und wiedergegeben. Die Dokumentation orientiert sich an der Programmstruktur und ist nach den acht Hauptthemen und 15 Unterthemen, sowie nach Eröffnungs-, Keynote- und Schlusssession gegliedert.

Neben dem hier vorliegenden Bericht sind zahlreiche Ergebnisse auf der Homepage der Konferenz (https://www.ini2021.com/) dokumentiert. Dort finden sich u. a. alle zur Konferenz eingereichten Abstracts nach Themen sortiert (https://ini2021.com/abstracts-2021/). Außerdem sind dort alle Poster archiviert (https://ini2021.com/posters-2021/). Alle Folien, die von den RednerInnen im Nachgang zur Konferenz den Veranstaltern zur Verfügung gestellt wurden, finden sich in einem Cloud-Archiv (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe). Die Folien sind dort nach Titel der jeweiligen Session und Name des Vortragenden abgelegt. Nicht zuletzt sind einige herausragende Beiträge im Rahmen der Sonderausgabe der Open Access Zeitschriften Environmental Research Letters (ERL) und Environmental Research Communications (ERC) veröffentlicht (https://iopscience.iop.org/journal/1748-9326/page/Focus_on_Reactive_Nitrogen).

2 Summary

2.1 A conference under COVID-19

In view of a growing world population, reactive nitrogen compounds are a key resource for food production. At the same time, human activities lead through various processes to leakages of reactive nitrogen into all environmental media. The increased presence of reactive nitrogen in the biosphere as a result has multiple impacts on the environment, human health, climate and biodiversity.

The pressure on the planet's resources and ecology is constantly rising. Measured against the "Planetary Boundary for Nitrogen", the amount of reactive nitrogen compounds emitted into the environment worldwide is far too high. Moreover, most of the UN Sustainable Development Goals (SDGs) are closely linked to the nitrogen cycle: Many SDGs are only achievable through a more conscious and efficient handling of nitrogen, for example by increasing the efficiency of nitrogen use in food production and reducing unwanted nitrogen emissions into the biosphere. This underlines the importance of new solutions for this complex problem; solutions that must additionally be aligned with the problems and overall conditions in the respective region. The resolution of the fourth United Nations Environment Assembly (UNEA-4) entitled "Sustainable Nitrogen Management"[2] also stresses the manifold threats of environmental pollution through anthropogenic reactive nitrogen with negative impacts on air quality as well as terrestrial, freshwater and marine environments. The resolution calls for effective measures to be taken in order to achieve the objectives of the SDGs.

The 8th conference of the International Nitrogen Initiative (INI2021) was dedicated to the following objective: to bring together scientists from throughout the world who are dealing with reactive nitrogen compounds in agriculture, industry, transport, soil, water and air. The aim of the conference was to share results, ideas and visions in order to improve the management of reactive nitrogen in such a way that hunger and poverty can continue to be reduced and further threats to human health, biodiversity, water, air and soil avoided at the same time. The conference also provided an opportunity for scientists to enter a dialogue with important political decision-makers and relevant interest groups. The concluding document of the conference, the Berlin Declaration, is based on the latest scientific findings and aims to stimulate wider-reaching political measures for effective and integrated nitrogen management.

[2] https://wedocs.unep.org/bitstream/handle/20.500.11822/28478/English.pdf?sequence=3&isAllowed=y

2.2 Germany as host

Alternating on different continents, conferences of the International Nitrogen Initiative (INI) take place about every three years. Previous hosts were institutions in the Netherlands (1998), the USA (2001), China (2003), Brazil (2007), India (2010), Uganda (2013) and Australia (2016). After the first conference in the Netherlands in 1998, INI2021 was the second time that the conference was organized from Europe. Germany was a host of the INI conference series for the first time. This is of special significance, since it was in Germany that scientists Fritz Haber and Carl Bosch invented industrial ammonia fixation around 100 years ago; a process which today safeguards food for a good half of the world's population on the one hand, but is, on the other hand, also the main source of the reactive nitrogen that leaks into the biosphere.

Since many environmental goals cannot be achieved in Germany either due to excessive nitrogen pollution of the biosphere, hosting the global conference was of great importance for Germany's environmental administration. In 2015, the Federal Ministry for the Environment (BMU) began coordinating activities in the area of integrated nitrogen reduction in Germany. The global exchange on the latest scientific findings concerning nitrogen reduction in the course of the INI conference was therefore acknowledged as an important cornerstone for integrated nitrogen policy in Germany. In addition, sharing their own experiences concerning integrated nitrogen reduction with an international audience in Berlin was a matter of particular concern for the Federal Ministry for the Environment and the German Environment Agency (UBA). For these reasons, the German Environment Agency, as a scientific agency under the authority of the Federal Ministry for the Environment, submitted an application to the INI to host the conference in Berlin. This application was approved on 4 July 2017.

With the German Environment Agency assuming the role of host, the importance of this environmental problem is highlighted at national level. In addition, the conference was co-hosted for the first time by a national ministry.

2.3 Organization

At the beginning of 2018, the German Environment Agency started to set up a Conference Secretariat. For this purpose, it was possible to secure project funds from the Federal Ministry for the Environment and issue a tender for a project to prepare, hold and follow up the conference. Event agency Akademie Dr. Obladen (ADO) and N^3 Nachhaltigkeitsberatung were recruited as project partners. The Conference Secretariat's tasks included, among others, selecting a venue in Berlin, designing the necessary communication media, communicating with participants, taking care of financial management, coordinating the scientific programme, planning a supporting programme, and assisting participants and the invited keynote speakers. In total, around 30 newsletters were sent out in about two years.

The Conference Secretariat remained in close contact with the INI Steering Committee for all important aspects related to organization.

2.4 INI2021 committees

To support the Conference Secretariat, a number of committees with specific advisory functions were set up:

- Two Advisory Committees: one local, one international. Eleven, respectively 16 distinguished experts from various nitrogen-related disciplines worked on the Advisory Committees. The two committees assisted the Conference Secretariat by providing suggestions and scientific recommendations regarding programme structure and priority themes, special sessions and potential keynote speakers. In close cooperation, all three groups jointly decided on the final conference programme. As important multipliers, the committees also helped to disseminate information about the conference within their networks.
- In addition, a Scientific Committee was set up, which was cross-disciplinary and comprised further international experts. This committee was responsible for the professional checking of the contributions submitted and decisions on their acceptance. It was composed of numerous members of the Local and the International Advisory Committees, the Conference Secretariat and other experts from science, administration, scientific associations and industry. This committee had 50 members in total.

Further information about the committees and their members can be found under the following link: https://ini2021.com/information/#committees

2.5 Impact of COVID-19

The original plan was to hold the conference at the beginning of May 2020. This had been preceded by two years of intensive planning and preparation. Due to the worsening COVID-19 pandemic at the beginning of 2020, the decision was made ten weeks before the start of the conference, in March 2020, to postpone INI2020; large-scale events were no longer possible. At this point in time, almost 250 presentations and 150 posters were considered confirmed, the scientific programme had already been published and around 300 participants had registered. Cancelling the five-day conference, which had been almost completely planned at this late stage, was complicated for both the organizers and the large number of participants who had already registered. In the following months, the uncertain forecast regarding the pandemic made further planning difficult. It was decided to postpone INI2021 first for six months and then for a full year, in the hope that the situation regarding the pandemic would improve.

On 4 May 2020, the day originally scheduled for the opening of the conference, a virtual event took place that had been organized at short notice. This was intended to underline the significance of the topic of nitrogen and offer a foretaste of the postponed conference. In the framework of the two-hour Zoom webinar, Professor Dirk Messner, President of the German Environment Agency and therefore also host, sent a video message in which he expressed his regret about the cancellation of the conference at short notice and his optimism that it would be made up for at a later date in Berlin. The webinar, in which about 300 scientists around the world participated, was moderated by INI chairpersons Professor David Kanter and Professor Nandula Raghuram. It can be viewed in full length at https://ini2021.com/virtual-event-2020/.

Finally, the plan was to hold the conference on 31 May - 3 June 2021. This was linked to the extension of the accompanying project and an increased budget. Initially, it was assumed that the conference could be held in a hybrid format. However, in October 2020, the organizers switched to an entirely virtual format: It was too uncertain whether in-person events on a larger scale would be possible again by the start of the conference. In addition, the hybrid format would have meant a considerable increase in costs, as IT and transmission systems would have had to be financed in addition to the facilities at the conference venue. This reorganization, with major adjustments to the programme, logistical modifications (including cancelling the contract with the venue, contracts with a virtual conference platform, reimbursement of participant fees) was extremely complex. The scientific programme also had to be revised, as various presentations and posters registered for 2020 in Berlin were withdrawn or no longer available for the conference postponed to 2021.

All in all, the 8th Global Nitrogen Conference was planned twice under the unforeseen conditions of the pandemic: firstly as an in-person event and secondly as an entirely virtual one.

2.6 Scientific programme

The conference's scientific programme was aligned with the heading "Nitrogen and the United Nations Sustainable Development Goals" and structured along eight thematic blocks with a total of 15 subthemes (https://ini2021.com/program/#scientific-program). The eight overarching thematic blocks were the areas Nutrition and Lifestyles (1), Agriculture and Food (2), Ensure Health, Clean Water, Air and Cities (3), Combat Threats for Biodiversity (4), Observing Global Challenges, Fluxes and Interactions between Different Drivers and Pressures (5), Closing the N Cycle: Innovations for Sustainable N Management (6), Integrated Science and Policy Approaches – Social and Public Awareness (7) and what were termed "Special Sessions" (8). Three special sessions on "Nitrogen Use Efficiency and Sustainable Nutrient Management", "Nitrogen Footprints" and "Nitrogen in Forests" formed part of the last block. These were registered with the organizers in the course of preparing the conference.

The conference documentation presented here is structured according to these eight thematic blocks.

Twelve months before the originally planned conference, the conference website https://www.ini2020.com was launched in May 2019, together with the invitation to submit scientific contributions on the eight main themes and 15 subthemes. By the deadline of 30 September 2019, the Conference Secretariat had received around 440 scientific contributions from 33 countries via the electronic platform used for the call for papers. Each abstract was reviewed in the selection process by two experts from the Scientific Committee. In addition, the Scientific Committee assisted the Conference Secretariat in assigning the presentations to the programme structure in terms of theme and with deciding whether a contribution should be accepted as a poster or a presentation. In this way, a total of 248 applications were accepted as presentations and 149 as posters, and 41 submissions were rejected.

No new call for papers was issued for the virtual conference in 2021. All scientists who had been invited for 2020 with a presentation or poster were asked whether they wanted to continue with their contributions. As a result of this poll, around 100 contributions were withdrawn. Since a small number of contributions were additionally accepted after review, the programme for the virtual conference ultimately comprised 191 presentations and 91 posters. Overall, due to the coronavirus crisis, about a quarter of the contributions originally registered for 2020 could not be shown. The 191 presentations were grouped under the 15 subthemes in such a way that a total of 36 parallel sessions were arranged.

40 contributions that had received the best appraisals in the review process were invited to publish their research results in a special issue of the scientific journals Environmental Research Communication and Environmental Research Letters. Over 20 outstanding papers from the conference have meanwhile been published in the open access portal of these journals (https://iopscience.iop.org/journal/1748-9326/page/Focus_on_Reactive_Nitrogen).

2.7 Keynote speakers

In cooperation with the Local and the International Advisory Committees, a list of suggestions for suitable keynote speakers was compiled in the run-up to the conference. The objective was to recruit distinguished scientists to give a keynote speech for the 15 subthemes. Regarding the composition of the speakers, great value was placed on achieving an even balance. As a consequence, it was possible to line up a group of keynote speakers that was almost equally composed of female and male representatives as well as speakers from all continents.

High-ranking political representatives were recruited for statements at the opening session: from UN conventions related to the topic of nitrogen, from the SDG Center for Africa, as well as from the host continent Europe, represented via a video message by Virginijus Sinkevičius, EU-Commissioner for Environment, Oceans and Fisheries https://clous.uba.de/index.php/s/uj0e7OX8wYAI4hi), and from the host country, represented by Svenja Schulze, Federal Minister for the Environment.

2.8 Pre-programme: Nitrogen in the host country Germany

In the run-up to the conference, the participants were sent preparatory materials: various short presentations in a stimulating format from the host country Germany on the national nitrogen problem and related historical and current approaches to solving it. Originally, these parts of the programme had been foreseen for an evening side event to the in-person conference. These presentations are available in a virtual format and can be viewed in full online at https://ini2021.com/pre-program-2021/.

2.9 Staging the conference

Staging the conference as an online event because of the coronavirus crisis led to particular logistical challenges. Due to the vast time differences between the Eastern Hemisphere (e.g. Japan and New Zealand) and the Western Hemisphere (e.g. British Columbia or Chile), it was decided to hold the conference only between 12.00 and 16.00 CEST (Central European Summer Time). As examples: For Japanese and Chinese participants this meant that the conference continued late into the night; for Mexican and Chilean participants getting up very early was required. Overall, a time window of four hours was available for each of the four conference days. With a daily time-window of about nine hours, twice as much time would have been available for an in-person conference in Berlin.

“Conference Compass”, a virtual event platform, was used to hold the conference. This online conferencing system offered the possibility to record and view all presentations beforehand. This meant that the programme was partially decoupled from the pure conference time, and it was possible for all keynote speeches and the 150 presentations to be held: All presentations from the parallel sessions had to be pre-recorded by the speakers and saved in Conference Compass. One week before the actual start of the conference, all presentations were online and could be viewed there in advance by the participants so that the contents could then be discussed in the respective live sessions.

The outcome was that only the panel discussions, the keynote speeches and the discussion rounds in the sessions were conducted as a live programme in the four-hour time window on the four days of the conference. A pool of international experts was available to chair all discussion rounds, both for the keynote speeches as well as the parallel sessions.

2.10 Concluding document: Berlin Declaration

The concluding document, the Berlin Declaration, was adopted on 3 June 2021, the last day of the conference. The draft was compiled by members of the INI Steering Committee together with the Conference Secretariat and with input from the Local and the International Advisory Committees. In the run-up to the conference, the draft was made available to all participants, who were also given the opportunity to comment.

The Declaration accentuates that achieving the SDGs is dependent on the unresolved nitrogen issue. It urges that all environmental impacts and the hidden costs of high nitrogen inputs are sufficiently taken into consideration and, beyond this, that conflicting goals in political action plans are recognized and resolved. The authors of the Declaration are, however, aware that now as before the problem of high nitrogen inputs is not fully acknowledged in public perception and in the political arena. As a consequence, the Declaration calls for better awareness of the problem. In this context, the unequal distribution of nitrogen use and leakages worldwide is explicitly highlighted. To solve the environmental problem, the Berlin Declaration argues for increased efforts to integrate sustainable nitrogen management into environmental policy endeavours at all levels and for ambitious national and international targets. Here it refers, among others, to the UN Colombo Declaration of 2019 and its goal of halving nitrogen waste by 2030.

The Berlin Declaration was signed by INI chairpersons Professor Nandula Raghuram and Professor David Kanter, as well as Svenja Schulze, Federal Minister for the Environment, and Dr Lilian Busse, Vice-President of the German Environment Agency, and has the backing of the INI2021 participants. The four-page document can be downloaded from the following link: https://ini2021.com/berlin-declaration/

2.11 Conference documentation

This documentation is a summary of all the results of the conference and provides links to those archived digitally. In the main part of this report, the conference presentations have been summarized, links provided to the abstracts and slides and the content from the parallel discussion rounds reproduced. As far as possible, the notes and summaries of the expert moderators were used and reproduced. The documentation follows the programme structure and is organized according to the eight main themes and 15 subthemes, as well as the opening, keynote and closing sessions.

In addition to the report presented here, many results are documented on the conference website (https://www.ini2021.com/). There you will find, among others, all the abstracts submitted to the conference sorted by theme (https://ini2021.com/abstracts-2021/). In addition, all the posters are archived there (https://ini2021.com/posters-2021/). All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe). The slides are archived there by title of the respective session and speaker's name. Last but not least, some outstanding contributions have been published in the special issue of the open access journals Environmental Research Letters (ERL) and Environmental Research Communications (ERC) (https://iopscience.iop.org/journal/1748-9326/page/Focus_on_Reactive_Nitrogen).

3 Berlin Declaration

The Berlin Declaration is an important outcome of INI 2021. The draft was prepared by members of the INI Steering Committee together with the INI 2021 Secretariat and with contributions by the International and Local Advisory Committees. In order to draw more attention to the major hazards of reactive nitrogen compounds, the Declaration is addressed to national governments and international organisations. This Declaration therefore refers to actual policy issues, activities by international organisations, and the work of INI and the International Nitrogen Management System (INMS) aiming at sustainable use of reactive nitrogen compounds. The drafted Declaration was disseminated shortly before the Conference to the registered participants of the conference. Comments by the delegates were reviewed by the INI chairs and the INI 2021 Secretariat. The final draft was adopted in the Closing Session. The scientific community should use the Declaration as a message for all relevant stakeholders, e.g. agricultural associations, health sector, traffic planners and for national environmental policy. The scientific basis of the Berlin Declaration is documented in an attachment reader (see annex). The declaration was signed by Svenja Schulze, Federal Minister for Environment, Nature Conservation and Nuclear Safety, Dr. Lilian Busse, Acting Vice-President of the German Environment Agency, Prof. Dr. Nandula Raghuram, Chair of the International Nitrogen initiative, Ass. Prof. Dr. David Kanter, Vice-Chair of the International Nitrogen initiative and more than 100 scientists attending the conference. The four-page document can be downloaded from the following link: https://ini2021.com/berlin-declaration/

3.1 Berlin Declaration on Sustainable Nitrogen Management for the SDGs

The 8th Global Nitrogen Conference (INI2021) was hosted virtually by the German Environment Agency during May 31-June 03, 2021, with more than 1000 registered participants from 64 countries. The participants have endorsed this document, the Berlin Declaration, calling for the sustainable management of reactive nitrogen compounds across all sectors of human activity as a crucial step towards achieving the UN Sustainable Development Goals (SDGs) by 2030. We applaud the enormous scientific and political progress made since the first International Nitrogen Conference held in The Netherlands in 1998, recognizing the environmental impacts of a vital resource and generating scientific knowledge to support public and private efforts to manage nitrogen more sustainably. We particularly applaud the resulting intergovernmental adoption of the first ever UN resolution on Sustainable Nitrogen Management in the fourth UN Environment Assembly (2019).

We recognize that better management of humanity's relationship with nitrogen is central to the success of the SDGs:

- Nitrogen is crucial to a healthy biosphere, given its role in sustaining life on land and below water, and is inextricably linked to the fate of carbon and other nutrients.
- The application of nitrogen inputs provides food and income to people across the world and has thus contributed substantially to reducing hunger and poverty. Still, lack of reactive nitrogen resources remains a critical challenge in the world's least developed countries, with nitrogen deficiency leading to soil degradation and food insecurity.

- The natural nitrogen cycle has now doubled in scale due to human activities, driven by intensive animal agriculture, over-fertilisation of agricultural land and fossil fuel combustion. Nitrogen's planetary boundary is one of only two (including biodiversity loss) that are estimated to have been substantially exceeded by humanity. The unique chemistry of the nitrogen cascade means that it exacerbates a range of environmental and human-health problems central to sustainable development, from air pollution and biodiversity loss in terrestrial and aquatic ecosystems, to climate change and pollution of drinking water.

- Over 2500 policies around the world touch on nitrogen management and loss. Two-thirds of policies in the agricultural sector focus on food production and economic development, leading to the underrepresentation of the environmental impacts of N use and its associated hidden costs. This illustrates the need to address the potential trade-offs and synergies between SDGs in nitrogen management policies.

We support ambitious goals at national and international scales, while acknowledging the unequal distribution of nitrogen use and loss across the world:

- The ambition to 'halve nitrogen waste'[3] by 2030, as agreed in the 2019 UN Colombo Declaration and recently embraced by a similar target in the EU Zero Pollution Action Plan, aligns with the current scientific understanding of the scale of ambition necessary to address the ecological and human impacts of nitrogen pollution.
- The International Nitrogen Initiative, with its global and regional representation of the relevant scientific community will continue to provide scientific support for evidence-based decisions at intergovernmental, regional and national levels, as a part of the "existing networks and platforms" and "existing relevant platforms" mentioned under (a) and (c) of the United Nations Environment Assembly (UNEA) resolution on Sustainable Nitrogen Management (UNEP/EA.4/L.14).
- Different countries and regions will necessarily prioritize different economic sectors and nitrogen sources depending on the distribution of nitrogen use and loss. The role of scientific advice and expertise is therefore especially important to enable targeted policy responses to the multiple challenges created by excess or insufficient nitrogen, considering it as an essential resource.
- The scientific community (INI) and other relevant stakeholders from civil society to industry and farmer organizations will support policy makers via the design and evaluation of integrated policy options. This includes:
  - Developing improved nitrogen management practices and technologies for widespread use at the farm-level,
  - Promoting recovery of nitrogen resources from animal manure, wastewater and industrial effluents,
  - Supporting the shift to healthy diets, based on foods with lower nitrogen footprints and a higher share of plant-based protein sources,
  - Educating relevant stakeholders and the general public on the dangers of N pollution to increase support for policy action.

[3]Total 'nitrogen waste' is considered as the sum of all forms of reactive nitrogen (N_r) pollution and loss, including anthropogenic denitrification to di-nitrogen (N_2), which is equally a waste of N_r resources. It includes both intentional and unintentional anthropogenic losses.

We, the scientists, practitioners and institutional representatives participating in INI2021 call for:

- A more prominent role for scientific advice in national and international policy processes, such as consideration of the recommendations from the First International Nitrogen Assessment, to be released in 2022. The International Nitrogen Initiative (INI) will play an important part in the UN Inter-Convention Nitrogen Coordination Mechanism (INCOM) in enhancing the role of science and evidence-based policy making to address the nitrogen challenge.
- More government and private sector funding for research, development, innovation, demonstration and deployment of new and existing technologies and practices that can help to achieve sustainable nitrogen management across all economic sectors, climates, agronomic conditions and development levels.
- Better coordination between the natural and social sciences to focus on research questions relevant to policy, including societal transition to more sustainable food and energy systems to enable holistic and coherent policies to improve nitrogen management.

We encourage the integration of sustainable nitrogen management objectives within environmental policy efforts across all scales to maximize the likelihood of improving humanity's relationship with nitrogen:

- Nitrogen management should be integrated within existing environmental policies, such as those focused on climate change, combating hunger and protecting biodiversity. This can be done while also developing new integrated national and international nitrogen policies that take a more coherent and easily communicable approach to nitrogen management in order to maximize synergies and minimize trade-offs. A promising example of this is the National Nitrogen Target proposed by the German Environment Agency.

- Holistic policy approaches require integrating the latest scientific understanding, particularly the need for systemic approaches to prevent, reduce and recycle nitrogen waste across the entire agri-food system (from fertilizer manufacturers to consumers) and beyond.

- Examples of best-practices exist on a regional level to promote integrated nitrogen management. For example, the Geneva Convention on Long-Range Transboundary Air Pollution (CLRTAP) especially considers impacts of nitrogen oxides (NO_x) and ammonia (NH_3) emissions in the context of the wider nitrogen cycle, and the South Asia Cooperative Environment Programme (SACEP) promotes regional co-operation on nitrogen and sustainable development.

Near-term opportunities to integrate sustainable nitrogen management within global policy efforts include:

- Make sustainable nitrogen management a focus of the UN Food Systems Summit in September 2021 – especially the post-Summit research and policy agenda – given its importance to delivering healthier, more sustainable and equitable food systems.
- Encourage the Parties to the UNFCCC to pay special attention to nitrous oxide (N_2O) as the third most abundantly emitted greenhouse gas, as new Nationally Determined Contributions (NDCs) are put forward in future Conferences of the Parties to the UN Framework Convention on Climate Change. Nitrous oxide mitigation is critical for reaching the Paris Climate Agreement's ambitious temperature targets. We welcome the #Nitrogen4NetZero initiative launched under the leadership of Sri Lanka in cooperation with the British High Commission ahead of the Glasgow Climate Conference (COP26). We welcome all countries to develop nitrous oxide mitigation targets under the principle of "common but differentiated responsibility" as well as other principles enshrined in the Rio Declaration on Environment and Development (1992) and reiterated in Rio+20.
- Support the establishment of a global nitrogen loss reduction effort in the post-2020 negotiations under the UN Convention on Biological Diversity linked to the Kunming Biodiversity Conference (COP15), building on the ambition outlined in the Colombo Declaration.
- Include integrated nitrogen management options in the review and potential future revision of the Gothenburg Protocol of the CLRTAP.
- Involve the International Nitrogen Initiative (INI) to support and enhance the Inter-Convention Nitrogen Coordination Mechanism, proposed in the UNEA-4/14 resolution on Sustainable Nitrogen Management, as an outcome of the GEF-UNEP-INI project "Towards International Nitrogen Management System (INMS)", so as to continue to play a crucial role in supporting and informing national and international efforts.

Signatures

3 June, 2021

Endorsed by the participants of the 8th Global Nitrogen Conference (INI 2021)

First Signatories:

Svenja Schulze, Federal Minister for Environment, Nature Conservation and Nuclear Safety

Dr. Lilian Busse, Acting Vice-President of the German Environment Agency

Prof. Dr. Nandula Raghuram, Chair of the International Nitrogen initiative

Ass. Prof. Dr. David Kanter, Vice-Chair of the International Nitrogen initiative

4 Pre-Programme

In the Pre-Programme, important contributions to sustainable nitrogen management were presented by German scientists. All these presentations can be found on the INI2021-website (https://ini2021.com/pre-program-2021/) and on YouTube.

The **Nitric Acid Climate Action Group (NACAG)** was launched by the German Ministry for the Environment (BMU) in 2015. NACAG's goal is to incentivize permanent mitigation of nitrous oxide emissions in all nitric acid production facilities worldwide. Nitrous oxide is an ozone-depleting greenhouse gas with a global warming potential 265 times that of carbon dioxide. Although these emissions can be mitigated technically relatively easily and cost-effectively, most nitric acid plants worldwide are not equipped with technology to reduce greenhouse gas emissions, given the absence of incentive mechanisms and regulations. The global mitigation potential in this sector is estimated to be around 1.8 gigatons of CO_2 equivalents over the next 10 years. NACAG offers technical support to its partner countries to develop long-term effective climate policies for this sector and to integrate these emissions into the Nationally Determined Contributions (NDCs) to the Paris Agreement. Under certain circumstances, NACAG provides financial support for the purchase and installation of greenhouse gas mitigation technology for eligible production facilities in its partner countries. More information about "Abating N2O in the nitric acid production!**"** can be found in the NACAG video (https://youtu.be/VU27KlgNba4).

1909, German chemist Fritz Haber, then professor of physical chemistry and electrochemistry at the Technical University of Karlsruhe, made one of mankind's most important discoveries: He developed the artificial synthesis of ammonia. In this way, a process was made available which delivered the nutrient element nitrogen in almost unlimited quantities for the production of fertilisers. Fritz Haber shared his discovery with the Badische Anilin- & Sodafabrik (BASF). At BASF he met Carl Bosch, who transformed the catalytic process into an industrial process. The **Haber-Bosch process at BASF** finalized the limited availability of fertilisers for food production. This was the crucial prerequisite for feeding the world's population that increased from 1.6 billion in 1900 to 6.8 billion in 2010. The links below illuminate the early history of the Haber-Bosch process at BASF in Ludwigshafen.

- 100 Years of ammonia synthesis: from the first mineral fertilizer to clean air (https://www.youtube.com/watch?v=pzFZ9TYizaw)
- 1902-1924: Age of Fertilizers (https://www.basf.com/global/en/who-we-are/history/chronology/1902-1924.html)
- BASF History (https://www.basf.com/global/images/about-us/history/BASF_Chronik_Gesamt_en.pdf).

Prof. Dr. Bretislav Friedrich, head of the research group "Interactions of molecules in and with fields" at the Fritz Haber Institute of the Max Planck Society in Berlin. maintains an abiding interest in the history of science. He gave a talk about the life of Fritz Haber: "**Ingenious scientist, inventor of warfare agents, Nobel Prize winner**". Fritz Haber was the winner of the 1918 Nobel Prize for Chemistry for his successful work on nitrogen fixation.

He was, however, a tragic figure: His revolutionary invention made it possible to feed more than two billion people in the world, but he also became known for his work in the development and use of chemical warfare agents in the First World War. Fritz Haber lost his wife to suicide after he started using warfare agents.

The talk of Bretislav Friedrich about Fritz Haber's life can be found on youtube: https://youtu.be/ymAvbqKJ0Vs

Dr. Heike Bach, CEO of VISTA (München, Germany) is an experienced scientist and specialist for remote sensing. With her work, she proves that digitisation is a chance to support sustainable agriculture and water management using environmental models and satellite image analyses. In her presentation "**Remote sensing techniques for optimum nitrogen management**" she demonstrated the benefits of digital twins in agriculture that are combined with information on nitrogen concentration in soil, nitrogen input from air and meteorological data yielding an optimum fertilization. The information provided by the system is used to avoid any fertilizer surplus or deficit. The talk of Heike Bach can be found on youtube: https://youtu.be/FRVBg2O-d5Y.

In the last contribution to the INI 2021 Pre-Programme, Prof. Dr. Dirk Messner, President of the hosting German Environment Agency, provided an overview of German research on the sustainable management of nitrogen. In his presentation, he also highlighted the agency's efforts to develop a national nitrogen target. Dirk Messner's message on "**Recent scientific assessments and recommendations to reduce nitrogen pollution in Germany**" can be accessed on youtube: https://www.youtube.com/watch?v=Sm_NKvKzMns

5 Program

The detailed scientific program of the conference can be accessed via the website of the conference: https://ini2021.com/program/#scientific-program

6 Key-Note Speaker

Prof. Dr. Tapan Kumar Adhya
Tapan Adhya is the Director of the South Asia Nitrogen Centre, New Delhi. Well-versed with natural resource management of tropical agro-ecosystem with flooded paddy as the model, he has worked on greenhouse gas emission and also studied on microbial ecology towards restoration of soil fertility in such system.

Dr. Vincent Aduramigba-Modupe
Vincent Aduramigba-Modupe is the Africa Centre Director of the International Nitrogen Initiative; and a Senior Research Fellow at the Institute of Agricultural Research and Training, Ibadan, Nigeria. He is a developmental soil scientist, with over 20 years' experience in integrated soil fertility management, nutrient budgeting and use efficiency, digital soil mapping and systems agronomy; and has published extensively in high impact factor journals. He was a recipient of the Israeli MASHAV, German CIPSEM, Australia ALAF and Chinese NDRC fellowships (among others) which enabled him to acquire specialized skills at the Technische Universität Dresden – Germany and University of Sydney – Australia. Vincent is presently working on the management and NUE of pro vitamin A cassava for enhanced livelihoods in Nigeria; and currently the Nigeria team leader of the recently EC approved H2020-MSCA-RISE-2019 INSA project involving 15 institutions in Africa and Europe.

Dr. Heike Bach
Heike Bach is founder and CEO of VISTA, a company now belonging to the BayWa Group. Digitisation is taken as chance to support sustainable agriculture and water management using environmental models and satellite image analyses. Core applications include site-specific fertilisation and yield forecasting.

Anna Engleryd
Anna Engleryd is a Senior Policy advisor at the Swedish Environmental Protection Agency. For the last 15 years she has been lead negotiator on air pollution for the Swedish Government in several international fora. Since 2014 she is the chair of the Executive Body to the UNECE Convention on Long Range Transboundary Air Pollution. She has a background in energy systems analysis and energy efficiency from the Swedish Energy Agency and served for many years as vice chair to the European Council for an Energy Efficient Economy.

Prof. Dr. Bretislav Friedrich
Bretislav Friedrich is the head of the research group "Interactions of molecules in and with fields" at the Fritz Haber Institute of the Max Planck Society in Berlin and honorary professor at the Technical University Berlin. Aside from his research in molecular physics, he maintains an abiding interest in the history of science and is engaged in efforts to eliminate weapons of mass destruction.

Asst. Prof. Dr. David Kanter
David Kanter is an Assistant Professor of Environmental Studies at NYU and Vice-Chair of the International Nitrogen Initiative. His research examines new policy options for addressing nitrogen pollution and how to manage the transition to a global food system consistent with the Sustainable Development Goals. Prior to his current position, David was a Postdoctoral Research Fellow at The Earth Institute at Columbia University. He received his BSc in Chemistry and Law from the University of Bristol in the UK and his MA and PhD in Science, Technology and Environmental Policy from Princeton University.

Dr. Caroline Makasa
Caroline Makasa is the Acting Director General at The Sustainable Development Goals Center for Africa (SDGC/A). Prior to Joining the SDGC/A, Caroline worked in the area of international trade promotion for many years. She started her career at the Export Board of Zambia as a market research officer in April 1999. This included conducting detailed market surveys, organising trade missions and buyer to seller meetings. Notably she led business delegations to numerous global trade fairs and exhibitions. She later served as a Senior Market Development Specialist at the Zambia Development Agency where she played a pivotal role in enhancing regional trade and Sustainable development. Furthermore, she also previously worked on projects such as the European Union Mining Sector Diversification Programme, the United Nations Industrial Development Organisation Trade Capacity Building Framework Programme and the World Bank Governance Partnership Facility Programme in Zambia and Uganda. Caroline holds a Master of Science degree in Sustainable Development from the University of London School of Oriental and African Studies, a Bachelor’s degree in Economics from the University of Namibia, and a Diploma in Environmental Management from Maastricht School of Management in the Netherlands.

Prof. Dr. Dirk Messner
Dirk Messner heads the German Environment Agency (UBA). He took office on 1 January 2020. Dirk Messner was Director of the Institute for Environment and Human Security at the United Nations University in Bonn and Co-Chairman of the German Advisory Council on Global Change (WBGU).

Prof. Dr. Annette Peters
Annette Peters is Director of the Institute of Epidemiology at Helmholtz Zentrum München and full Professor of Epidemiology at Ludwig-Maximilians-Universität München. As head of the KORA study in Augsburg and the German National Cohort, her main research interest today is to understand the role of epigenetics, metabolism and immune activity in the interaction of genes and the environment.

Prof. Dr. Nandula Raghuram
N. Raghuram is the current Chair of the International Nitrogen Initiative and a Professor of Biotechnology at Guru Gobind Singh Indraprastha University, New Delhi, India. He co-founded the Indian Nitrogen Group, co-organized the fifth INI Conference (N2010) in New Delhi, co-led and co-edited the Indian Nitrogen Assessment and is currently co-leading the South Asian N assessment under INMS and South Asia Nitrogen Hub. He also facilitated the Indian Govt led resolution on Sustainable Nitrogen Management adopted by UNEA4 in March 2019. His lab has recently discovered the phenotype for nitrogen use efficiency in rice and is working towards characterizing the genotype and identifying the candidate genes for NUE in rice.

Professor Dr. Johan Rockström
Johan Rockström is Director of the Potsdam Institute for Climate Impact Research and Professor in Earth System Science at the University of Potsdam.
Rockström is an internationally recognized scientist on global sustainability issues, where he led the development of the new Planetary Boundaries framework for human development in the current era of rapid global change. He is a leading scientist on global water resources, with about 25 years of experience from applied water research in tropical regions, and more than 150 research publications in fields ranging from applied land and water management to global sustainability.
Aside from his research helping to guide policy, Rockström consults several governments and business networks. He also acts as an advisor for sustainable development issues at noteworthy international meetings, such as the World Economic Forum, the United Nations Sustainable Development Solutions Network (SDSN) and the United Nations Framework Convention on Climate Change Conferences (UNFCCC). Supplementary, he chairs the advisory board for the EAT Foundation and the Earth League.

Svenja Schulze
In March 2018, Svenja Schulze took up office as Federal Minister for the Environment, Nature Conservation and Nuclear Safety of Germany. In 2010, she was appointed Minister for Innovation, Science and Research in North Rhine-Westphalia; she held this position until 2017. She attended the Ruhr University-Bochum and graduated in German studies and political science.

Dr. Carly Stevens
Carly Stevens is a plant ecologist and soil biogeochemist at Lancaster University in the UK where she is a senior lecturer. Carly is particularly interested in the impacts of nitrogen deposition on semi-natural habitats, something she has investigated in a number of countries and habitats. Lancaster University is one of the leading research universities in the UK.

Prof. Dr. Mark Sutton
Mark Sutton is based at the UK Centre for Ecology & Hydrology (UKCEH), Edinburgh, where his research focuses on human alteration of the nitrogen cycle, linking field, landscape, national, continental and global scales. His work focused first on the behaviour of just one nitrogen compound, ammonia, integrating from emissions, air chemistry, deposition and environmental effects. His current research brings together all nitrogen forms and their multiple impacts on the environment with a focus on mobilization and policy development. He is Director of INMS for UNEP and the GEF, a co-chair of the UNECE Task Force on Reactive Nitrogen, Director of the GCRF South Asian Nitrogen Hub and vice chair of the Global Partnership on Nutrient Management.

Prof. Dr. Friedhelm Taube
Friedhelm Taube is professor in Grass and Forage Science/Organic Agriculture and Director of the Institute of Crop Science and Plant Breeding at Kiel University, Germany. In March 2019 he was additionally appointed Special professor in Grass based Dairy Systems at Wageningen University and Research (WUR), the Netherlands. He has 25 years of experience in forage and grazing lands. His research has focused on the physiology, management and use of forages in multipurpose systems.
As a recognized expert in the evaluation of nutrient losses due to crop management, Dr. Taube has contributed to numerous assessments of the Scientific Advisory Board of Agricultural Policy,

Food and Consumer Health Protection (WBAE) at the Federal Ministry of Food and Agriculture, Germany.

Dr. Norbert Taubken
Norbert Taubken has been Business Director at Scholz & Friends Reputation since 2007. Together with his colleague Christiane Stöhr he set up the strategy unit on corporate responsibility and sustainability within the network of Scholz & Friends. For more than 15 years, he accompanies CR strategy processes and sustainability topics within the for-profit-sector. His portfolio includes stakeholder management, impact valuation, and non-financial reporting. ALDI Süd, Audi, Coca-Cola, Hugo Boss, Microsoft, Telefónica, TÜV Nord, Xing, and the German Council for Sustainable Development (RNE) belong to the list of his clients. Norbert Taubken holds a PhD in Chemistry and a state exam as teacher. He gives lectures on CSR and business ethics at the Hamburg School of Business Administration (HSBA) and at Deutsche Presseakademie (depak). Taubken has been appointed member of the board of wellcome gGmbH and the Good Textiles Foundation. Additionally, he is founding member of Berlin Social Academy and Deutscher Fussballbotschafter e.V.

Dr. Aimable Uwizeye
Dr. Aimable Uwizeye is interested in global change towards sustainable livestock sector. He is a Livestock Policy Officer at the Food and Agriculture Organization of the United Nations (FAO) in Rome, Italy. He has more than twelve years experience in livestock development, animal health and environmental assessment of the global livestock sector.

Prof. Dr. Harold van Es
Harold van Es is a Professor of Soil Science at Cornell University, USA, the 2016 President of the Soil Science Society of America, and Special Advisor for Digital Agronomy at Yara International. He is the lead inventor for Adapt-N, computational technology for crop nitrogen management which received the $1M Tulane Nitrogen Reduction Challenge prize.

Prof. Dr. Maren Voss
Leibniz-Institut for Baltic Sea Research in Warnemünde, Germany. My research focuses on the biogeochemistry of nitrogen including microbial rates measurements and nitrogen fixation in the ocean and the Baltic Sea in particular. Studies on the effects of eutrophication in coastal regions include estuaries and river plumes as well as hypoxic systems.

Dr. Stefanie Wolter
Stefanie Wolter is working at the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety since 2016. At the ministry, she coordinates the work on an integrated nitrogen strategy and works on the topic of transformative environmental policy. Stefanie studied biology and then completed a doctoral degree as civil engineer in sanitary environmental engineering.

Prof. Dr. Chaoqing Yu
Chaoqing Yu received his Ph.D degree from the Geography Department at the Pennsylvania State University in 2005. Now he is the chief scientist at the AI-for-Earth Lab, a joint laboratory of the Tsinghua University's Earth System Science Department and the Tsinghua Cross-strait Research Institute. His recent research focuses on applying biogeochemical models to quantify the relations among food security, water resources, and water quality over broad-scale geographic regions. Nitrogen plays a central role in the biogeochemical processes. He is interested in understanding how technology and socioeconomic drivers have changed the pattern of nitrogen flow in China, how much the synthetic nitrogen has contributed to grain yields, what is the safe

boundary for nitrogen discharge to the regional water environment, and what are the solutions to restore the water quality in light of the small sized farming system. Lessons learned from China are beneficial for many other regions in the world where water pollution is increasing because of excessive nutrient discharge.

Prof. Dr. Sophie Zechmeister-Boltenstern
Sophie Zechmeister-Boltenstern is Professor for Soil Science and Soil Microbiology, Director of the Institute of Soil Research and Deputy Director of the Department of Forest and Soil Sciences, at the University of Natural Resources and Life Sciences, Vienna, Austria. Her research focuses on the role of soils as sources and sinks for atmospheric trace gases with particular attention to the underlying microbial processes. She aims to provide management recommendations for better nitrogen use efficiency and adaptation to climate change. She is a member of the KIÖS of the Austrian Academy of Sciences.

Asst. Prof. Dr. Xin Zhang
Xin Zhang is an Assistant Professor at University of Maryland Center for Environmental Science. Her research investigates socioeconomic and biogeochemical processes that affect the global nutrient cycle and the sustainability of agricultural production. She holds a Ph.D. in Environmental Studies from Yale University and held a postdoctoral position on environmental policy at Princeton University.

7 Opening and Key-Note Sessions

7.1 Opening Session

Moderator
Ms. Heike Leitschuh

7.1.1 Opening statements

7.1.1.1 Welcome from the organizers (Stefanie Wolter, Markus Geupel)

The representatives of the hosts, Mr. Markus Geupel (German Environment Agency) and Ms. Stefanie Wolter (German Ministry for Environment, Nature Conservation, and Nuclear Safety) started the Opening Session of INI 2021 with a warm welcome to all participants. They regretted that the meeting in Berlin could not happen due to the pandemic. This is the first virtual INI! And it is the first one addressing all SDGs.

Stefanie is responsible for the development of the German integrated nitrogen strategy; Markus is a scientific advisor to the Agency with special interests in the nitrogen cycle and integrated solutions to solve environmental problems related to it and ecological problems caused by surplus nitrogen. Together with a number of other scientists, he is busy in the calculation of national flows of reactive nitrogen compounds. They thanked the Advisory Committees, the Scientific Committee and the other members of the Secretariat. Markus also described shortly the difficulties that came up with the switch from a physical to a virtual conference.

7.1.1.2 Nitrogen matters! (Nandula Raghuram, David Kanter)

The INI Chair, Mr. Nandula Raghuram looked back to the roots and thanked some colleagues who are working with the INI since the very beginning. He highlighted the successful international recognition of the nitrogen issue. The UNEA4 Resolution in 2019 and the Colombo Declaration, which was published some months later, mark a real breakthrough for the recognition of an underestimated global hazard. INI Vice Chair Mr. David Kanter mentioned the responsibility of scientists for awareness raising with respect to the nitrogen issue. The co-operation with social scientists and economists is an important prerequisite for political solutions. Therefore, it was a very good idea to align the INI2021 conference with the SDGs.

7.1.1.3 Nitrogen and German Policy (Svenja Schulze)

Germany’s Minister for Environment, Ms. Svenja Schulze, stated that nitrogen inputs are one of the most pressing global environmental problems. There is still a lack of the public awareness needed to implement suitable solutions as compared to other urgent global problems. Numerous measures introduced in Germany in recent years have led to decreasing nitrogen emissions. This trend has to be supported – in the same way as increasingly ambitious climate action measures. Svenja Schulze called for action at national, EU and global level. She supported the idea of an ambitious national nitrogen target 2030.

7.1.1.4 Nitrogen in the EU (Virginijus Sinkevičius)

In his statement, Commissioner Virginijus Sincevičius, presented the European Green Deal aiming at a turnaround of economy towards ecologically sound products and production. As to nitrogen, the Commissioner named agricultural policy as the first priority because of surplus of reactive N compounds endangering soils and their biodiversity that will at least decrease their fertility. The European Union has recognised the nexus between resources, nutrients, climate and other issues linked to nitrogen. There are numerous instruments to be aligned, e.g. the integrated nutrient management action plan. The video message can be watched or downloaded here: https://clous.uba.de/index.php/s/uj0e7OX8wYAI4hi

7.1.1.5 Nitrogen in context of UNEP (Leticia Carvalho)

Ms. Leticia Carvalho, Head of UNEP's Marine and Freshwater Branch, stressed the need to reduce meat consumption in order to decrease the use of N fertilizers. She also pointed out mineral fertilizers should be substituted as far as possible by organic material. Recycling of reactive nitrogen compounds is necessary as well to avoid wasting nitrogen. The UN campaign which started in 2019 tackles lack of awareness for nitrogen problems. The nitrogen issue must be brought into the centre of environmental policy. Leticia Carvalho highlighted the activities of Sri Lanka and some other countries aiming at the successful reduction of nitrogen emissions.

7.1.1.6 Nitrogen in context of FAO (Maria Helena Semedo)

Ms. Maria Helena Semedo, Deputy Director General of the FAO reminded the participants of the enormous problems for nutrition that came with the pandemic. Though N fertilizers are needed to combat hunger, the imbalance of nutrients is an enormous challenge. She particularly deplored the inequality in the distribution and use of fertilizers that has increased during the Covid 19 crisis. She mentioned circular bio-economy as key. But farmers need incentives, e.g. better access to fertilizers on one hand and technical instruments to use N in a sustainable manner to avoid wasting N. Answering a question by the moderator Heike Leitschuh for trade-offs between the SDGs 2 and 14,15 etc., she highlighted the co-operation between FAO and UNEP in the Global Soil Partnership also aiming at sustainable management of nitrogen.

7.1.1.7 Nitrogen and Air Quality (Anna Engleryd)

Ms. Anna Engleryd, Chair of the Executive Body to the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP), introduced the binding protocols of CLRTAP as a good example for sound environmental policy based on careful scientific work. She called for an inter-conventional N mechanism as a common roof for existing Conventions, campaigns and non-binding protocols. Political success on the nitrogen issue requires co-operation between different countries, international organisations, and scientific structures.

7.1.1.8 Nitrogen and SDG in Africa (Caroline Makasa)

Ms. Carolin Makasa, Acting Director General of the SDG Center for Africa, underpinned the low agricultural productivity in Africa leading to critical situation for nutrition. Sustainable nitrogen management suffers from inadequate national capacities, lack of political commitment and also deficient regional solidarity. Therefore, partnerships between governments as enshrined in SDG 17 would be an important contribution to mitigate the nitrogen dilemma. She expects this conference to develop blueprints for dialogues on N issues.

7.1.2 Summary of the session

In conversation with Mr. Nandula Raghuram and Mr. David Kanter, Chairs of the INI, Heike Leitschuh asked for their expectations for the future. Following their statements, the planetary boundary for reactive nitrogen compounds should be accepted as a global goal. Instead of a general "N Convention" a combination of existing and new Conventions would be an enormous progress. They highlighted the Janus face of nitrogen – on one hand necessary for any form of life, but a mess in the case of surplus. With respect to INI 2021, David deplored the virtual format that hampers new personal contacts. Raghuram expected the conference to enhance the potential of INI for a better understanding between scientists and sound communication with the public and political bodies.

7.2 Key Note Session Day 1

Moderator
Ms. Heike Leitschuh

7.2.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

7.2.1.1 Nitrogen: of planetary importance for Earth resilience (Johann Rockström)

Mr. Johan Rockström, Director of the Potsdam Institute for Climate Impact Research, presented the challenges on the way back to a sustainable global circle of nitrogen. He highlighted justice as one of the keys for N management. With respect to climate change, some indicators (e.g. the melting of glaciers) reveal that the earth is already on the edge of potential tipping cascades. With respect to nitrogen, there are no global tipping points, but many regional problems that in sum are as important as climate change. The surplus of nitrogen is clearly reflected by enormous nutrient intoxications of coastal waters, but also of open oceanic areas. He introduced the “N valve” that limits further input of reactive nitrogen into the anthroposphere. In his conclusion, Johan Rockström presented consequences for food, particularly focusing on healthy diets. Strong sustainability should be introduced as a yardstick for economic activities. According to him, it is possible to feed 10 billion people, but only with a completely other distribution of nutrients as today.

7.2.1.2 Vision for future N management (David Kanter)

Mr. David Kanter, Assistant Professor at NYU (USA), presented his vision for future N management starting with the goal of the Colombo Declaration. His provocative question was: “Is the same system that created the N pollution problem the best one to manage it?” He called for brave scientists promoting the transformation to sustainable N management. David introduced four major requirements for transformation:

- Transform the way farmers get nutrients to plants and animals
- Transform the way we manage and make food off the farm
- Transform the way we make N policy
- Transition in a way that respects different national priorities, cultures and future generations

In response to the moderator's question about suitable tools, he mentioned economic instruments and regulations that have proven useful in the CFCs issue. In response to a question from the auditory, he applauded Germany for the new 2030 goal and many activities already started by the forerunners.

7.2.1.3 Ecologic intensification - new approaches to increase nitrogen use efficiency in dairy farming (Friedhelm Taube)

Mr. Friedhelm Taube, Professor at the University of Kiel (Germany), took up David's ball from the field and asked how to make a "U-turn" regarding nitrogen pollution. He presented results of a pilot experiment for milk production from North Western Germany. The project: "Eco-efficient pasture based milk production" that started in 2016, focusses on an approach to fulfil relevant ecosystem services linked to dairy systems. There is a comparison between the pasture-based milk production as an alternative to the usual confinement system with HF-breeds. The first results demonstrate that a rotational grazing system based on spring calving can sustainably produce milk under German conditions. Annual dry matter yields of non-fertilised grass clover swards were comparable to those realised in Ireland with a fertiliser application of 150 kg N ha^{-1} . Friedhelm Taube concluded that the transformation of about 1/3 of grassland back to former peat land would be one important step for the "U-turn". The dairy systems should be completely transformed. This would also reduce the social costs enormously that are higher than the present subsidies for the farmers.

After his speech, Prof. Taube answered two questions from the audience:
Question: What should be done instead with the peatland fields for N & climate benefits?
Answer: These peatlands can be used for 'wet agriculture' (so-called Paludi cultures) for producing raw material e.g. for thatched roof, for PV systems or for nature protection, e.g. flora fauna habitat measures.

Question: The problem of ley systems is intense mineralization following ploughing that results in higher risks of N emission. How do you mitigate that risk?

Answer: The crops following a 2,5 year ley system have to be spring crops obligatory, that means tillage is only allowed from 1st of February onwards in order to avoid nitrate leaching due to autumn tillage – we do have a lot of evidence about that; on Lindhof experimental farm cows graze the ley in early March (beginning of a third ley year) a last time, before the field is ploughed and then especially oats following leys in spring benefit from the residual nitrogen transfer from grass-clover roots in a range of 100-120 kg additional N uptake per ha ending up in 6 t ha^{-1} oats harvested.

7.2.1.4 New Trends in Nitrogen Management: Africa Perspective (Vincent Aduramigba-Modupe)

Mr. Vincent Aduramigba-Modupe Ph.D., Senior Research Fellow at the Institute of Agricultural Research and Training, Ibadan (Nigeria), and INI regional Director, highlighted the high population growth rates, expected to more than double by 2050. All these people need nutrition. In Africa, there are "low N" regions as well as "high N" regions. The Africa Soil Information System is based on a robust technology and provides information for sound fertilization. Vincent presented some examples from Nigeria. He pointed out that the transformation needed in African N management requires "tsunami-like changes, not ripples". This is all the more important because the situation is worsening due to some megatrends, e.g. changing diets, climate change, soil degradation. In his conclusions he focused on capacity building, strengthening of partnerships, knowledge transfer and information exchange.

7.2.1.5 Improving plant NUE: From phenotype to genotype (Nandula Raghuram)

Mr. Nandula Raghuram, Professor for Biotechnology, New Delhi (India), deplored the complexity of definitions for Nitrogen Use Efficiency (NUE), e.g. related to grain weight, biomass weight and other reference points. The lack of clear definitions complicates the research for efficient phenotypes and genotypes. Fortunately, N-responsive transcriptomes for many crops are now available. It is necessary to come to a short list of the minimal traits and genes with respect to NUE. He presented the approach to validate candidate genes through reverse genetics after phenotypic and genotypic characterization. He demonstrated for a number of rice varieties that germination correlates with crop duration, yield and NUE. From recent research it is clear that G-proteins regulate N-response/NUE in rice. This opens the door for six high priority rice varieties for further investigation and application. Numerous questions showed the high level of interest in this lecture, but could not be answered due to lack of time.

7.2.1.6 INMS Project introduction and overview (Mark Sutton)

Professor Mark Sutton, UK Centre for Ecology and Hydrology, Penicuik / Midlothian, and Project Director of the INMS, stressed INI as a catalyst for bringing the N issue forward. Policy for better N management suffers from a severe communication problem: Many stakeholders do not recognize the damages by surplus nitrogen. He highlighted the enormous number of activities and measures included in the UNECE Air Convention and its Protocols that has been built on since about 40 years. According to his lecture, the most important transformation covers a switch from linear to circular N management. This is part of the Colombo Declaration calling for “halving nitrogen waste”, i.e. a sharp decrease of surplus nitrogen.

7.3 Key Note Session Day 2

Moderator
Mr. Cargele Masso

7.3.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

7.3.1.1 Nitrogen in India (Tapan Adhya)

Professor Tapan Adhya, Director of the South Asia Nitrogen Centre, New Delhi (India), highlighted the situation in South Asia comprising eight countries with a population of 1.86 billion people, i.e. 25% of the global population, who share only 14% of the world's arable land. These figures describe the enormous challenge for South Asia to feed the population and to keep its environment. He mentioned two special problems: Strong N exchange over the thickly populated crops and huge amount of animal faeces. With respect to the increase of the total emissions of NO_x by > 90% and emissions of NH_3 and N_2O by about 35% between 2000 and 2014, South Asia can be regarded of one of the world's hot spots. The use of N fertilizers is as high as in Europe, but steadily increasing. Smaller irrigated areas are characterized by intensive use of fertilizers whereas fertilization is far lower on larger, rained areas. The high emissions of reactive N compounds are reflected by pollution of ground water, lakes, waterways and of the ocean around the peninsula. Tapan presented a number of general strategies to mitigate hazards from surplus N. He deplored some important barriers also including lack of co-ordination within the governments of the region.

7.3.1.2 Digital Agriculture and Nitrogen: Science, Implementation and Policy (Harold van Es)

Harold van Es, Professor of Soil Science at Cornell University (USA), compared the economic outcomes of high and low fertilizer use. Very high N input yields more crops, but is also more expensive and usually does not pay off. On the other hand, environmental costs increase with more N fertilization. He presented a "sustainable N balance" of about 50-75 kg N ha^{-1} per year for the US Midwest. As precision management of crop N is critical, balancing the N input affords a complex management in a multi-objective environment. The available data driven technologies fulfil the conditions for precision management drawing environmental profits.

7.3.1.3 Nitrogen in livestock systems including regional characteristics and inequalities (Aimable Uwizeye)

Dr. Aimable Uwizeye , FAO Livestock Policy Officer, differed between livestock systems that are embedded in local cultures and economics, and large farms for livestock that are linked to global trade. The demand for animal food is continuously increasing triggered by low process for cereals, energy improved technologies for feeding and breeding, and low prices for farmland. As the supply chains for fodder are long, there are many areas with dense farming of livestock without adequate possibilities to retain or use manure (e.g. China). Livestock farming contributes about one third of all human-made N emissions. In case of mixed dairy and beef intensive agriculture, hotspots with very high emissions of N_r can be found, e.g. South Asia, China, New Zealand, Europe. He recommended to study the Japanese circular bioeconomy that is driven inter alia by a food waste recycling law: Thus, high-quality meat can be produced, whereas feeding costs are in the range of 50% as compared to conventional farming. Aimable called for a global convention to combat nitrogen pollution.

7.3.1.4 How Nitrogen influences meeting UN SDG for Africa (Caroline Makasa)

Caroline Makasa, Acting Director General of the SDG Center for Africa, presented the benefits and hazards by nitrogen reflected in the SDGs, negative impacts are related particularly to goals 15.3, 3.9, 2.4. Africa has the lowest Nitrogen fertilizer use (i.e. about 3.3% of the world's total consumption) with an input of 15 kg N ha^{-1} in 2017. She assessed a fertilization rate of 181 kg ha^{-1} yr^{-1} to feed itself by 2050 that significantly exceeds the Abuja target of 50 kg nutrients. Caroline also recommended that African Governments should widen the scope of the Abuja declaration to better reflect the needs and socio economic contexts of African farmers as well as the Sustainable Development Goals.

7.3.2 Panel discussion

Cargele Masso explained that Dr. Till Spranger, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Berlin (Germany), substituted Anna Engleryd in the panel discussion because she was not able to join the Conference on day 2 and to speak about air pollution nitrogen.

Then, the moderator opened the panel discussion with the question how to combat imbalances in livestock farming. There is a big economic issue due to the importance of feedstock for the national economies. Changes in livestock farming afford a deep insight into cultural and economic roots of the society. According to Aimable Uwizeye, reduction of N input and N emissions is first choice instead of reducing the density of cattle.

A second question focused on the “right N rate” particularly with respect to the target proposed by Caroline Makasa. Harold van Es mentioned the combined social and environmental responsibility of governments – therefore, reduction or optimization of N input should be the first step.

Can relocation of intensive agriculture mitigate the N surplus problem? Tapan Adhya disagreed because of the regional differentiation of crops. But according to Till Spranger, there are other agricultural sources that should be considered, i.e. NH_3 emissions from stables and slurry application in the fields. He therefore asked for an integrated approach which comprises large regions aiming at a balance of reactive N compounds by exchange. Tapan Adhya explained how balanced N management is experienced in India, but this is hampered by existing subsidies.

Summing up several questions from the audience, the moderator asked the panellists for political and economic strategies to solve the nitrogen issue. Till Spranger pleaded for integrated N policies though this is difficult to communicate in the public as experienced in Germany: Integrated N approaches did not yield better threshold goals up to now. The Dutch example (“Dutch nitrogen crisis”) has shown that even elaborated policy measures can run into trouble. Due to the economic and ecological links in Europe, activities of the Commission would be welcome. Till recommended to establish and develop an inter-conventional mechanism instead longing for a nitrogen convention. Carolin Makasa called for joint know-how transfer integrating practitioners and policy. With reference to experience from U.S. agriculture, Harold van Es pointed out that economic incentives, i.e. expenditures and cost savings, should be realized on the stakeholder level to achieve the desired goals. Till Spranger mentioned the enormous social costs of environmental pollution, e.g. air, whereas the reduction of emissions at the source is rather inexpensive.

Detailed Questions and answer with relation to Key-Note Session 2 are documented in the Annex (Key-Note Session 2).

7.4 Key Note Session Day 3

Moderator
Jan Willem Erisman

7.4.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

7.4.1.1 The history and future perspectives of Baltic Sea Eutrophication (Maren Voss)

Prof. Dr. Maren Voss (Research Institute for the Baltic, Warnemünde, Germany) presented results from a joint German / Scandinavian research group. The Baltic is heavily polluted by nutrients (N and P surplus) leading to high concentrations of bacteria and seasonal algae blooms. Though mitigation measures are in place since about twenty years (based on the HELCOM Convention), many problems still resist, particularly in the bottom water layers, e.g. oxygen depletion as a consequence of eutrophication and loss of bottom fauna. She explained the mechanisms of this vicious cycle: Microbes gain energy from the conversion of reactive N compounds, mostly nitrate for primary production but also via fixation of N_2 resulting in the formation of ammonium that reduces oxygen in the bottom layer. Less oxygen leads to the enrichment of ammonium, but also of phosphate that is released from anoxic sediments. This environment fosters the reproduction of cyanobacteria which increase nitrogen fixation. Moreover, silica is reduced due to damming in the catchment areas. As silica is necessary for diatoms, the concentration of these organism decreases reinforcing the pollution because diatoms are fodder for microorganisms that clean the bottom. However, the restoration of the Baltic is possible. The recovery process can be sped up eliminating more phosphate from effluents or by importing oxygen into the bottom areas. But as the mechanisms in the bottom water and between surface and bottom layers are not quite clear, research work should be continued.

7.4.1.2 Nitrogen – Friend or Foe of Soil Organisms? (Sophie Zechmeister-Boltenstern)

Prof. Dr. Sophie Zechmeister-Boltenstern (Director of the Institute of Soil Research, University of Natural Resources and Life Sciences, Vienna, Austria) took the participants on a journey below ground. There is about a million of species living in soil. What happens if one of these species is lacking? The consequences depend on the specific function of this species and its interlinkages with other important species. Soil organisms are main drivers for the N cycle, i.e. N_2 fixation, nitrification, denitrification. N is the limiting factor in high latitudes, whereas P is the limiting factor in low latitudes. Higher N inputs e.g. in forests lead to an acceleration of the N cycle in soils thus increasing nitrogen mineralization, but inhibiting other processes. This effect is used to slow down the degradation of lignin thus maintaining a higher concentration of soil carbon. High N inputs in forests can lead to saturation: She presented experimental results that prove loss of functional funghi. In case of nitrogen surplus, microbial diversity decreases and ecosystem processes for the production of biomass slow down. She concluded her speech with the guiding sentence “Nitrogen is a treacherous friend of soil organisms.”

7.4.1.3 How increased nitrogen availability has influenced biodiversity of terrestrial ecosystems (Carly Stevens)

Dr. Carly Stevens is a plant ecologist and soil biogeochemist (Lancaster University, UK). She continued the session with an overview of the consequences of increased N availability to terrestrial biodiversity, i.e. eutrophication, acidification, direct toxicity, disturbance of other systems. She presented loss of heath from heathlands and other impacts on biodiversity in Europe caused by long-lasting nitrogen input. The richness of grassland species is decreasing parallel to increasing deposition of inorganic nitrogen compounds. She demonstrated enormous changes of the composition of lichens as a result of N deposition over more than fifty years. Fortunately, soil and plant tissue chemistry can recover in short time, but the recovery of plant species needs many years. Presumably, alternative stable states arise during periods with high N input that hamper the restoration of former biodiversity. Carly reported that there are still many knowledge gaps with respect to higher trophic levels. She concluded with an appeal for better communication and awareness raising.

7.4.1.4 Nitrogen Strategy in Germany (Stefanie Wolter)

Dr. Stefanie Wolter (German Ministry for Environment, Berlin) introduced national policy measures aiming at the reduction of N_r emissions. She pointed out that many steps are necessary to come to an integrated nitrogen strategy. The emissions from the industry and partially also from traffic were reduced significantly, but emissions from agriculture remained at a high level now accounting for about 66% of all N_r emissions in Germany. Therefore, an ambitious multi-segment nitrogen target has to be developed for 2030 (see presentation by Markus Geupel, 7b – Educational aspects, public awareness, risk communication (policy) I). But the introduction of further measures and their enforcement remain difficult due to many stakeholders that are affected. Public dialogues and consultations are used to bring this issue forward.

7.4.2 Panel discussion

The moderator highlighted the compliments from the audience for the presentations. Then he started the panel discussion with the question how to communicate and to bring the problems closer to the public, particularly in countries with less participation of citizens as compared to Western Europe. The presentation of external costs is an interesting instrument for awareness raising, even if the internalization of these costs is very difficult. (see also below) In the further course of the discussion, the question was raised whether critical loads for all compartments are known to set the right targets – what is necessary, enough and too much? The panellists agreed that this particularly difficult in case of soils and sediments. Referring to the talk of Johan Rockström, the issue of tipping points for N was discussed. There are no global tipping points, but they depend on the regional ecosystems, e.g. very different for forests according to the type of trees, type of soil etc. The results of the session also demonstrated that numerous links between surplus of N_r and other global threats have to be taken into account, e.g. higher temperature changing the effects of N_r.

Detailed Questions and answer with relation to Key-Note Session 3 are documented in the Annex (Key-Note Session 3).

7.5 Key Note Session Day 4

Moderator
Kevin Hicks

7.5.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

7.5.1.1 Air Pollution Health Effects (Annette Peters)

Annette Peters, Director of the Institute of Epidemiology at the Helmholtz Centre and Professor of Epidemiology at the University of München (Germany) presented interactions between inhaled toxic particles with the lung and their partial penetration of the blood circle. This can lead to a weakening of the immune system. From an epidemiological perspective, fine particles are linked to increased mortality. Many aerosols include particles, e.g. smoke from combustion, but also N species (e.g. NO_2, NO). Which of the components are particularly dangerous to human health? NO_2 decreases the lung function of asthmatics. Following a number of epidemiological studies, continuous exposition to NO_2 increases the mortality; however, the results show high variance. She mentioned that the mechanisms of air pollution and health are not fully understood and should further investigated. Annette called for lower threshold limits for N compounds and particles in Europe, but she would appreciate international co-operation to reach global standards on the European level.

7.5.1.2 Managing Nitrogen for sustainable agriculture production: Integrating Social and Ecological Perspectives (Xing Zhang)

Xin Zhang, Professor at the University of Maryland Center for Environmental Science (USA), pleaded for a broader scope for nitrogen management in agriculture, i.e.

- to converge socioeconomic and ecological processes,
- to shift the focus from the production to the entire system,
- to do interdisciplinary and transdisciplinary research.

NUE trends vary significantly around the globe. She highlighted the low NUE in the agro-food-system, i.e. 16% for meat production, whereas NUE is about 43% in crops. The problems with NUE are mostly driven by N losses in livestock production. This can only be changed by the integration of numerous stakeholders along the agro-food-chain and transdisciplinary and transnational work for a sustainable agriculture matrix. She presented some indicators for the three dimensions of sustainability. She recommended the developing countries to take a close look at the mistakes and successes of nitrogen management in the industrialized countries. Political leadership for balanced agro-systems is necessary.

7.5.1.3 N matters – turning risk communication into agenda setting (Norbert Taubken)

Dr. Norbert Taubken, Business Director at Scholz & Friends Reputation (Berlin, Germany) reminded the auditory of the intense media echo on the occasion of the contribution by Minister Svenja Schulze at this conference. This was an exciting example of how to move the N issue on the public agenda. He explained the difference between campaigning and agenda setting – the latter is less costly, but a complicated task. Agenda setting should be built upon a very condensed key message that can be spread through the media. This is challenging, because there is so much scientifically sound information. For agenda setting, the question has to be answered: What is the importance of nitrogen to an individual and his or her life in the world? Rational arguments and emotions have to be well balanced and the wording has to be appropriate. Norbert presented a short fairy tale comparing nitrogen with Cinderella. He introduced emotional links of some basic molecules thus demonstrating positive and negative signals connected to these molecules. He concluded with three statements: For scientists, the N cycle is very interesting, but too complex for the public. For citizens, “nitrogen” is part of the air but without any function. N compounds from animal faeces spread on the fields is a stinky business. Would “Nitrogen enables nutrition of the world?” be an appropriate starting point for the agenda setting?

7.5.2 Discussion

The discussion focused on communication issues, particularly on the wording for agenda setting. It was agreed that research should be presented in terms that resonates with the public and decision-makers. But nitrogen should not be framed exclusively in positive words. There was a proposal from a participant: "No nutrition without N - let´s not waste N!". Kevin Hicks appreciated the ideas presented and discussed in this session. He concluded that INI should look for easy to understand messages that are scientifically sound.

8 Theme 1: Nutrition and lifestyles sessions

8.1 Session 1b - Responsible consumption and production and feedbacks in the N cycle

Moderator
Jill Baron

8.1.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

8.1.1.1 The groundwater diet: trade-offs and benefits of healthy dietary choices in the context of nitrate pollution (Martine Hoogsteen)

Martine Hoogsteen and Job Spijker analysed a large dataset of the Dutch Minerals Policy Program to gain more insight into shifts in dietary patterns in the context of groundwater pollution. She presented a nitrate footprint per crop type based on groundwater monitoring results which was linked to the nutritional contents and daily recommended intake levels of those crops. They concluded dietary shifts towards more plant-based diets could lead to increased nitrate leaching under equal land management. In the discussion, Martine answered some questions about the influence of the areas used for production of vegetables and different soil types.
https://ini2021.com/the-groundwater-diet-trade-offs-and-benefits/

8.1.1.2 Sustainable food systems from a nitrogen perspective (Adrian Leip)

Adrian Leip and co-workers presented two methods for visualizing sustainable food systems from a nitrogen perspective:

(i) elementary flow of nitrogen between food system 'spheres', i.e. food production, food chain, and consumers, as well as resource management systems including waste management and the environment;
(ii) (ii) food system functions including the stakeholders and their power to induce the food system.

https://ini2021.com/sustainable-food-systems-from-a-nitrogen-perspective/

8.1.1.3 Evidence-based Nitrogen Indexes for Sustainable Agro-food Systems (Xia Liang)

Xia Liang and co-workers presented a methodological framework to build evidence-based N indexes for global food at varying levels of detail and complexity. In case of realisation, it would provide a comprehensive assessment of N_r loss for individual food items, a robust prediction of associated environmental and socioeconomic impacts to make global agriculture more sustainable, less polluting and more profitable.
https://ini2021.com/evidence-based-nitrogen-indexes-for-sustainable-agriculture/

8.1.1.4 Assessing future nitrogen fertilizer demand and use for the shared socioeconomic pathways (J. M. Mogollon)

J.M. Mogollon et al. performed model calculations assessing the future N input requirements and N use in agriculture for five shared socioeconomic pathways. The results revealed a range of possible future synthetic fertilizer inputs from 85 - 260 Tg N yr^{-1}. Only the so-called sustainability scenario (global NUE > 60%) met the acceptable limits of excess N in developing regions.
https://ini2021.com/assessing-future-nitrogen-fertilizer-demand/

8.1.1.5 Nutrient-extended input–output analysis for food nitrogen footprint (Azusa Oita)

Azusa Oita and co-workers developed and applied a novel approach, the nutrient extended input-output (NutrIO) analysis to evaluate the N footprint. They linked a MFA of N to economic transactions along the important supply chains. The N footprint of Japan in 2011 was estimated to 21.8 kg N inh^{-1} yr^{-1} with a share of about 80% from agriculture and fisheries. The integrated assessment of N footprint demonstrated the importance of contribution of industrial N to the food supply chains in complex agro food systems.
https://ini2021.com/nutrient-extended-input-output-analysis-for-food-nitrogen-footprint/

8.1.2 Moderators summary

The moderator welcomed a large number of participants who joined this session. All contributions highlighted important new ways of both looking at N flows and possibly mitigating them, from individual food choices to global scale flows. The moderator concluded that all the methods presented require more work for refinement. She highlighted that all presentations provide increased perception at personal to international information groups of the problems associated with N and possible intervention points where changes can be made.

9 Theme 2: Agriculture and food sessions

9.1 Session 2a – Livestock production and nitrogen balance and nutrient cycle

Moderator
Gabriele Wechsung (Borghardt)

9.1.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

9.1.1.1 An integrated approach to nutrient management on dairy farms (Shabtai Bittman)

Shabtai Bittman and his co-workers investigated the integrated effects of a number of innovative measures for improving nutrient efficiency of dairy farms. Cropping measures reduced leaching for both crops (grass and corn), but manure measures (trailing horse or shoe?) increased N_2O emissions, which was mitigated with a nitrification inhibitor. They suggested land allocation for corn.
https://ini2021.com/an-integrated-approach-to-nutrient-management-on-dairy-farms-abstract/

9.1.1.2 Influence of soil properties on N_2O and CO_2 emissions from excreta deposited onto tropical pastures in Kenya (Zhu Yuhao)

Zhu Yuhao and colleagues studied the importance of soil properties on N_2O emissions from cattle excreta (dung, urine) for five typical tropical soils in Kenya using intact soil cores in both dry and rainy seasons. They found that soil properties have minimal effects on N_2O from dung, but significant effects on N_2O from urine. Their results call for a revision of the IPCC guidelines for calculating N_2O emissions from excreta deposition on tropical rangelands; because the calculated N_2O emission factor (EF) from this study was one magnitude lower than the default EF used by the IPCC.
https://ini2021.com/influence-of-soil-properties-on-n2o-emissions/

9.1.2 Moderators summary

In the following, the extensive discussion notes of the moderator (questions and answers) are documented completely:

Shabtai Bittman:

1) In one of the slides in the beginning of the presentation you reported about an annual N surplus of 40 kt N for this region. One important source is the 'imported animal feed' of about 20 kt per year. If we look at your farmlets, especially farmlets 3 and 4, I was wondering, will these measures help to reduce the amount of the 'imported animal feed'? Did you recognize any effect? Answer: Yes, measures are intended to reduce feed and fertilizer imports into the regions through greater farm production and manure use. There has not been a nutrient policy and no one had done these calculations before by improving crop yields which has definitely had impact and reducing fertilizer use. We have had-piece meal success both in our region and in adjacent US where our relay cropping which has been mandated. We expect manure separation will be increasingly adopted- already it is being used to generate bedding. BTW, improved animal NUE for both dairy and poultry has helped but has led to more production. Our integrated approach is new to policy makers and we hope this to be educational to demonstrate that joined up practical solutions are possible to counteract agricultural cynics and pessimists.
   Additional efforts include farm-customized real-time computer modelling of soil N (on hold due to funding), three-way manure swapping, and double circular economy which includes both C and N. The latter we are exploring as a peri-urban approach with farm groups and Metro Vancouver.
2) Are farmers interested in taking up your recommendations? How do you communicate with them? Answer: An example of success is the relay cropping in the USA fostered by policy but now very well entrenched. In Canada, policy has been lacking so interest has been modest. But this is suddenly changing as new manure rules to protect ground water are being rolled out and there are strict new national mandates on vastly reducing N_2O which should inevitably result in less fertilizer use and better manure use. The GHG regulation is a really big deal now in Canada, and a national environment program which we have not had in agriculture before. We expect N adoption to vastly increase with the new regulations especially the GHG. There are also habitat programs that will improve use of P.

Zhu Yu Hao:

1) Why do you think the N_2O was positively correlated with the pH. Many prior studies have found that liming tends to decrease emissions. So why was this different? Answer: Increased soil pH would generally decrease the N_2O and N_2O+N_2 ratio during the denitrification process. This is the reason that liming tends to decrease emissions. On the other hand, for acidic soils, increased soil pH would also increase soil microbial activities, especially nitrification which as a consequence may increase the N_2O emission. The soils used in our study are slightly acidic and fairly similar in pH (pH range: 5.3–6.4), we speculate that the latter played a more important role in our study.
2) What do you think about the urine and dung effect on denitrification? Answer: Both urine and dung contain large amounts of water and also labile carbon and nitrogen which favours denitrification.

3) What would be effective measures to prevent N_2O emissions during the application of urine and dung (manure)? Answer: Some mitigations have been developed. The most widely used are the application of nitrification and urease inhibitors. Some scientists also suggest applying biochar and liming materials. Diet manipulation is considering effective by balancing the protein to energy ratio without negative effect on animal performance which means reducing the crude protein and increasing the fibre in the developed countries. You can find more information from the article "Greenhouse gas emissions from excreta patches of grazing animals and their mitigation strategies".
4) N_2O emissions are much lower from tropical soils in your experiments in Kenya than from IPCC 2019. Tropical rangeland: overall EF N_2O for cattle excreta = 0.13% vs 2% IPCC 2019. What do you propose? Do we need different IPPC defaults for different regions? Answer: The EF of 2% was developed by IPCC in 2006 and to reduce the uncertainties, the IPCC developed a refinement with separating excreta types and climate conditions. The overall cattle excreta EF by IPCC refinement under dry climate is 0.2% which is a bit higher than our results of 0.13%. This is mainly due to the lower urine-N and dung-N split in Africa because of the poor-N feed diet. IPCC always recommends developing the country-specific EF and many countries have their own EF, like New Zealand, UK.
5) In your study the excreta-N ratio of dung to urine was 66:34, in IPCC 2019 refinement the ratio was 34:66! How do you explain this discrepancy? Answer: The IPCC 2019 refinement uses the N partitioning between urine and dung of 60:40 based on a summary of trials primarily from New Zealand with a high supply status in the animal production system. In contrast, the animal in SSA are mainly fed with high fibre, low digestibility, and low protein content diet (grazing or crop residuals) and even suffer from food shortage during the dry season. The split between how much N is excreted as dung or urine depends on the dietary protein intake and on its digestibility. Above the required protein intake will increase the proportion of N excreted as urine, while at low concentrations of digestible protein, the proportion of N excreted as dung will increase.

9.2 Session 2a – Livestock production and nitrogen emissions

Moderator
Helmut Döhler

9.2.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

9.2.1.1 Sources of nitrous oxide from intensively managed pastures (Johannes Friedl)

Johannes Friedl and co-workers studied sources of N_2O in soil with ^{15}N tracers. They found an exponential response to soil water content across all soils investigated. Heterotrophic nitrification to N_2O turned out to be an important source.
https://ini2021.com/sources-of-nitrous-oxide-from-intensively-managed-pasture-soils/

9.2.1.2 Effect of nitrogen-reduced diet on NH_3 and N_2O emissions of dairy cows on pasture (Christof Ammann)

Christof Ammann and his colleagues demonstrated that the emission of N_2O and NH_3 from dairy cattle is decreased by 19% if the cows are only fed with pasture grass as compared to a system with 25% maize silage substituting grass. They stated that the N_2O emission factor currently used in the Swiss GHG model is too high.
https://ini2021.com/effect-of-nitrogen-reduced-diet-on-nh3-and-n2o-emissions-of-dairy-cows/

9.2.1.3 Effects of lime application management on nitrous oxide emission and nitrogen use efficiency: An example from an Irish intensive grassland system (Ognjen Žurovec)

In a long-term study of Irish grassland, Ognjen Žurovec and co-workers demonstrated the positive effect of continuous liming on N_2O emissions. They also recorded grass yield and N uptake. It was concluded that liming is a low-cost measure yielding higher soil fertility and decreasing emissions.
https://ini2021.com/effects-of-lime-application-management-on-nitrous-oxide-emission/

9.2.1.4 Long-term measurement of ammonia and nitrous oxide emissions from Australian feedlots (Mei Bai, not present in the discussion)

Mei Bai and her co-workers presented some results from an extensive study on feedlot systems in South and North Australia aiming at valuable data for GHG emissions. They found that brown coal added to soil reduces the emission of NH_3. The results suggested that the IPCC methodologies for estimation of emissions from feedlots overestimated N_2O emissions by up to 50%, underestimated NH_3 emissions by a factor of 3 times.
https://ini2021.com/long-term-measurement-of-ammonia-and-nitrous-oxide-emissions/

9.2.1.5 High animal comfort and low emissions in a new housing system for pigs - conceptual study and first results from pilot farms and laboratory experiments (Helmut Döhler)

Helmut Döhler presented the results of a project aiming at significant reduction of environmentally and climate-relevant emissions and, on the other hand, at the socio-political requirements for animal-friendly livestock farming. Together with his co-workers, he developed system that fulfils all these requirements thus demonstrating a holistic perspective for livestock farming.
https://ini2021.com/high-animal-comfort-and-low-emissions-in-a-new-housing-system-for-pigs/

9.2.2 Moderators summary

The moderator summarized the most important results of the session:

- IPCC default emission factors are higher than measured N_2O emissions from cow pastures.
- Improvement of soil pH with liming is a low-cost management change, which has the potential to increase soil productivity and reduce N_2O emissions in intensive grassland ecosystems.
- Soil research demonstrates the proportion of nitrified N emitted as N_2O is an exponential function of soil water content.
- Promising housing systems combining low emissions and animal welfare are under development; the pilot system has already proven to meet several sustainability targets.

He highlighted the following important new information from the presentations:

- N adapted feeding of grazing cows reduces N excretion, ammonia and nitrious oxide losses, N_2O emission factors of cow urine is lower than IPCC default.
- Clear dependency between soil pH and N_2O emissions, the lower pH the higher emissions.
- Soil research in Australia highlights the contribution of heterotrophic nitrification to N_2O production.
- New housing system for finishing pigs with an airconditioned (heatable, coolable) comfort area and a small defecating (toilet) area were developed.

9.3 Session 2b - Optimizing the efficiency of nitrogen use in crop production (crop production & nitrogen emissions) I

Moderator
Alberto Sanz-Cobena

9.3.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

9.3.1.1 Ammonia volatilization and nitrous oxide emissions from organic fertilizers applied to arable soils in the North China Plain - possible trade-offs and mitigation approaches (Marco Roelcke)

Marco Roelcke and colleagues from China and Germany reported the results from three field experiments in the North China Plain under different cropping systems during three different years and seasons. They used different organic fertilizers depending in their availability in the region and compared different application methods. Ammonia and nitrous oxide emissions were measured in situ following fertilizer application. Incorporation and furrow application of fertilizers resulted in lower NH_3 but higher N_2O emissions. Due to varying global warming potentials (using the IPCC standard emission factors) "best practice" recommendations cannot be concluded.
https://ini2021.com/ammonia-volatilization-and-nitrous-oxide-emissions-from-organic-fertilizers-applied-to-arable-soils/

9.3.1.2 Fate of 15N-nitrogen fertiliser applied in high rainfall zone dairy pastures of southern Australia (Helen Suter)

Helen Suter and her co-workers investigated the soil and fertiliser contributions to dairy pasture nitrogen uptake. They used urea enriched with ^{15}N as tracer. Pasture harvested on the fields (micro plots) simulated grazing. Greatest uptake of applied N occurred in the first two harvests after fertilization. However, more than 77% of the pasture N came from the soil. The authors concluded that utilising soil N reserves combined with lower fertiliser inputs could improve NUE in dairy systems.
https://ini2021.com/fate-of-15n-nitrogen-fertiliser-applied-in-high-rainfall-zone-dairy-pastures/

9.3.1.3 Low nitrate leaching determined by threshold for cover crop biomass (Chiara De Notaris)

Chiara de Notaris and her colleagues studied nitrate leaching during four years in a long-term crop rotation experiment (Foulum, Denmark), and the effect of legume-based cover crops. Cover crops reduced nitrate leaching by approximately 60%, but this effect varied from year to year. This was similar for legume and non-legume cover crops. But different crops exhibited different levels of nitrate leaching. The research group identified thresholds in cover crops biomass, above which nitrate leaching was reduced to a low and stable level.
https://ini2021.com/low-nitrate-leaching-determined-by-threshold-for-cover-crop-biomass/

9.3.1.4 Reducing N runoff during irrigated cotton production (Graeme Schwenke)

Graeme Schwenke and his colleagues studied N runoff after flood-furrow irrigation of Australian cotton fields. They demonstrated that N runoff during fertigation can be high, particularly when irrigation application efficiency is low. Runoff N loss can be reduced by ceasing N input once runoff begins. Runoff losses from pre-plant N can be reduced using either less N (split), nitrification inhibitor-coated urea or polymer-coated urea.
https://ini2021.com/reducing-n-runoff-during-irrigated-cotton-production/

9.3.2 Discussion

The lively discussion focused on the following subjects:

- Emissions from fields in the North China Plain: Alternative methods for NH_3 measurement in field experiments? Comparison of N loss patterns from fertilizers with different C/N ratio? Further impacts of NH_3 emissions, i.e. $PM_{2.5}$ formation?
- Fate of N after fertilization to dairy pasture: Significance of N mineralization? Losses from soil to the environment? Relocation processes within the soil?
- Nitrate leaching from fields covered with legumes: Potential reduction of N-application in the following season? Emissions of N_2O and NH_3 from covering crops? Are there modelling simulations to upscale the results from this research?
- Runoff from cotton fields: Vertical leaching or horizontal loss outside of the paddock? Method for sampling and analysis of NH_3? Can irrigation be used as NH_3 abatement strategy through fertilizer incorporation?

9.4 Session 2b - Optimizing the efficiency of nitrogen use in crop production (crop production & nitrogen emissions) II

Moderator
Shabtai Bittmann

9.4.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

9.4.1.1 Quantification and mitigation of ammonia emissions from paddy fields in subtropical central China (Jianlin Shen)

Jianlin Shen and co-workers designed an automatic and continuous ammonia emission measuring system to quantify ammonia emissions from paddy fields. For mitigating ammonia emission from paddy fields, a field experiment was conducted with treatments of reduced N application rate, deep application of basal fertilizer and use of urease inhibitor. Thus, the variations of NH_3 fluxes could be monitored just in time. The researchers observed a large daily and seasonal variation of NH_3 emissions. They demonstrated that deep application of N fertilizer and using urease inhibitor reduced the emissions by > 50%.
https://ini2021.com/quantification-and-mitigation-of-ammonia-emissions-from-paddy-fields-in-subtropical-central-china/

9.4.1.2 Mitigation of nitrous oxide emissions from horticultural crops and implications for the Montreal Protocol (Ian Porter)

Ian Porter, David Riches and David Kanter described extremely high N_2O emissions from Australian horticultural crops. Farmers use high amount of inorganic fertilisers and manure to produce multiple crops on the same soil. Despite the availability of mitigation technologies and practices, there has been little uptake by farmers. Therefore, the authors propose to add N_2O to the Montreal Protocol.
https://ini2021.com/mitigation-of-nitrous-oxide-emissions-from-horticultural-crops/

9.4.1.3 Leaching of dissolved nitrogen and carbon from winter cover crop in Mediterranean Central Chile (Osvaldo Salazar)

Osvaldo Salazar and his colleagues examined the combined effects of N fertilisation during the maize (Zm) cropping and cover crop inclusions vs Zm-fallow on dissolved inorganic N, dissolved organic N, total dissolved N and dissolved organic carbon leaching from a coarse textured soil in Mediterranean Chile. Lowest percolation was yielded in case of crop rotation with Zm, optimal N fertilisation (250 kg N ha^{-1}) and a grass cover crop
https://ini2021.com/leaching-of-dissolved-nitrogen-and-carbon-from-winter-cover-crop/

9.4.1.4 Interactive effect of nitrogen and potassium on nitrogen use efficiency in wheat under saline conditions (Abdul Wakeel)

The group of Abdul Wakeel presented a study under saline-sodic conditions as found in large regions of Pakistan. Fertilisation leads to high volatilisation rates of ammonia. The investigation focused on the interactive effect of N and K on NUE and ammonia gas losses.
https://ini2021.com/interactive-effect-of-nitrogen-and-potassium-on-nitrogen-use-efficiency-in-wheat/

9.4.2 Moderator's summary

Four speakers from different regions and production systems discussed an important N issue and their efforts to mitigate. These include: soil salinity on NUE and ammonia loss from wheat production in Pakistan (Wakeel), leaching of N_{min} and N_{org} from corn-cover crops in Central Chile (Salazar), NH_3 emissions from paddy fields in Central China (Shen), N_2O emissions from intensive horticulture in southern Australia (Porter). These talks discussed several measures such as fertilizer inhibitors, fertilizer placement, and nutrient management, cover crop selection as well as the import role for innovative policy (Porter) and the need for better research methodology (Shen). In combination this session showed well a cross section of environments and crop systems with a central and unifying theme: improving reactive N management. Each researcher illustrated his/her issue based approach to mitigating reactive N through reducing inputs and reducing losses. It demonstrates the difficulty of sweeping technical or policy solutions that would serve and not threaten invaluable food production in each region. The lesson learned here is the ongoing need worldwide to sharpen practical N technologies to underpin policies that are proposed at a global level. It is also important to capture farm data on adoption and impact of new technologies.

The general discussion concerned the mitigation practices and clarification of contexts and on methodical improvements. The moderator remarked that a conference dedicated to novel methods to mitigation reactive N might be more efficient than current meetings where this is intermingled with other goals. Categories of losses might be pasture, fertilizers, manure storage and spreading, processing of manures and other wastes, N fixation and crop rotations, beef feedlots, etc.

9.5 Session 2b - Optimizing the efficiency of nitrogen use in crop production (fertilizers)

Moderator
Maximilian Hofmeier

9.5.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

9.5.1.1 Release dynamics and crop recovery of Controlled Release Fertilizers (CRF) (Cristina Martinez)

Cristina Martinez and her co-workers compared the release dynamics, three-dimensional soil distribution, and crop recovery of nitrogen from polymer coated (PCU) and plant oil coated (POCU) urea to that from granular urea applied in an Australian Vertisol soil. While the controlled release fertilizers (CRFs) slowed the release of N into the soil solution, no clear yield or crop N uptake advantages were observed. Answering a question from the auditory, Cristina explained possible reasons for the different N release pattern between lab conditions and field conditions.
https://ini2021.com/release-dynamics-and-crop-recovery-of-controlled-release-fertilizers-crf/

9.5.1.2 Sustainable plant nutrition and nitrogen (Tom Bruulsema)

Tom Bruulsema mentioned the improvement of nourishment in the last sixty years though the global population has more than doubled. This is partially due to a sixfold increase in fertilizer use. To improve nitrogen use efficiency and to reduce the wasting of nitrogen, the principles of 4R Nutrient Stewardship should be implemented.
https://ini2021.com/sustainable-plant-nutrition-and-nitrogen/

9.5.1.3 Slow but sure: the potential for slow-release nitrogen fertilizers to increase crop productivity and reduce environmental damage in Nepal (Naba Raj Pandit)

Naba Raj Pandit gave an overview of a number of field trials performed in Nepal to assess the effect of slow release of nitrogen fertilizers (polymer coated urea (PCU) and urea briquette) on NUE and crop productivity of maize and rice. In both cases, NUE increased enormously up to 98% (PCU) and 58% (briquettes), respectively as compared to conventional urea.
https://ini2021.com/slow-but-sure-the-potential-for-slow-release-nitrogen-fertilizers-to-increase-crop-productivity/

9.5.1.4 Assessing nitrogen availability in bio-based fertilizers: effect of vegetation on mineralization patterns (Hongzhen Luo)

Hongzhen Luo and her co-workers studied nitrogen dynamics in soil with and without vegetation, under fertilization of synthetic N fertilizer (calcium ammonium nitrate, CAN) and bio-based N fertilizers (pig manure and liquid fraction of digestate). The latter ones had a higher rate of N mineralization in the maize growing experiment as compared to the incubation experiment.
https://ini2021.com/assessing-nitrogen-availability-in-biobased-fertilizers/

9.5.1.5 Improving organic amendment use in Australian vegetable production (David Riches)

David Riches and his co-workers presented a calculator that supports farmers to develop more efficient nutrient application programs providing both economic and environmental benefits. This tool is based on modelling the release of nutrients from organic amendments with field validation in commercial vegetable cropping.
https://ini2021.com/improving-organic-amendment-use-in-australian-vegetable-production/

9.5.2 Moderator's summary

The presentations in this session mostly reflected vegetable fertilization in Australia and Nepal with extremely high nitrogen application rates. There are no special approval procedures for new fertilizers in both countries.

N inhibitors and CRFs mostly exhibited the expected effects. In one case, no positive effect could be observed due to high precipitation and high mineralization. The moderator mentioned the need for ecotoxicological investigations as well as further research about the fate of the polymers and chemical agent.

The moderator underlined that no speaker had information about the fate of the polymers and chemical agents that are applied together with fertilizers. Therefore, further research in this field is necessary. Although the agronomical advantage of slow and controlled release fertilizers is quite obvious, there is no information about the effects on soil organisms, the leaching potential to ground water or the accumulation in the soil. However, knowledge about these impacts on the environment are absolutely required before SRFs and CRFs can be applied to soils on a much broader scale.

9.6 Session 2b - Optimizing the efficiency of nitrogen use in crop production (fertilizer and water application)

Moderator
Tapan Adhya

9.6.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

9.6.1.1 Effect of irrigation frequency and water quality on N losses from vertisols (Shahar Baram)

Shahar Baram and his co-workers conducted a field study in a drip irrigated Avocado orchard planted on a wastewater degraded montmorillonite clay soil in Israel. They tested different fertigation/irrigation frequencies and also used fresh as well as treated waste water. They demonstrated that the irrigation water quality (e.g. content of chloride) and the irrigation frequency should be accounted for to mitigate N_2O emissions and nitrate leaching.
https://ini2021.com/effect-of-irrigation-frequency-and-water-quality-on-n-losses-from-vertisols/

9.6.1.2 Impact of banding enhanced efficiency nitrogen fertilizers on nitrogen use efficiency in agriculture (Chelsea Janke)

Chelsea Janke and her colleagues examined some enhanced efficiency fertilizers (EEFs) in banded applications to learn about the mechanisms of NUE in this case. Laboratory and field experiments were performed. Banding has a significant impact on EEF efficacy. Benefits may be realized if the specific EEF technique is matched to key soil physico-chemical properties.
https://ini2021.com/impact-of-banding-enhanced-efficiency-nitrogen-fertilizers-on-nitrogen-use-efficiency-in-agriculture/

9.6.1.3 Allelopathic crop residue mulches improve nitrogen use efficiency and productivity of wheat (Sardar Alam Cheema)

Sardar Alam Cheema et al. studied the influence of crop residue mulches and different synthetic nitrogen fertilizers on soil health and productivity of wheat. In all field trials, mulch improved N uptake, protein contents of grains, NUE, the nitrogen harvest index and yields.
https://ini2021.com/allelopathic-crop-residue-mulches-improve-nitrogen-use-efficiency-and-productivity-of-wheat/

9.6.1.4 Optimizing Water and Nitrogen Use Efficiency (WUE & NUE) with Airjection® Irrigation (D. Goorahoo)

D. Goorahoo and co-workers reported results from long-standing studies with air injection into soils. Yields of melons and wheat increased significantly as compared to control areas. The authors suggest that NUE is positively affected because the denitrification genes population changes significantly after air injection. Impact on N fixation or ammonia oxidation were not observed.
https://ini2021.com/optimizing-water-and-nitrogen-use-efficiency-wue-nue-with-airjection-irrigation/

9.6.2 Discussion

From the discussion, two main conclusions were drawn by the moderator:

- Further studies on the different formulations of slow release urea and soil interaction should be conducted.
- The impact of seasonal variation on N_2O emission under application of treated wastewater and freshwater needs to be further investigated.

9.7 Session 2b - Optimizing the efficiency of nitrogen use in crop production (conventional management)

Moderator
Xiaotang Ju

9.7.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

9.7.1.1 N source and tillage management: Effect on nitrous oxide emissions and barley yields in a rainfed Mediterranean area (Guillermo Guardia)

Guillermo Guardia and his co-workers explored the combination of tillage management with different nitrogen fertilizers in a barley field. N_2O emissions could be minimized without any tillage and urease and/or nitrification inhibitor with even increasing yields under rainfed Mediterranean conditions. The discussion of his presentation focused on the main barrier in the use of inhibitors under rainfed conditions and on the effect of tillage management on soil C-stocks over time.
https://ini2021.com/n-source-and-tillage-management-effect-on-nitrous-oxide-emissions/

9.7.1.2 Fertigation of Orchards - Spatial Variability in N Usage and Losses (Shahar Baram)

Shahar Baran et al. combined ground measurements with areal imagery to identify the spatial variability in the N status of the various trees in an orchard. The collected data can be clustered into site specific management. In case of utilization of slow-release fertilizers, NUE shall be considerably improved, i.e. increase of yields and reduction of N losses. In the discussion, Sharan answered a question regarding the inclusion of N-unfertilized areas: There were no plots/areas without N application, because the objective was to optimize N fertilization in a commercial orchard. He welcomed the idea from the audience to work with ^{15}N to estimate N recovery in crop.
https://ini2021.com/fertigation-of-orchards-spatial-variability-in-n-usage-and-losses/

9.7.1.3 Mining soil nitrogen threatens Australian wheat (Shu Kee Lam)

Shu Kee Lam et al. investigated the partial N balance (PNB) for agroecosystems, particularly wheat. They found a severe imbalance between N input and N output, i.e. ~70 % of the calculated PNB was > 1 indicating mining of N from soils. An input of about > 80 kg N ha^{-1} yr^{-1} is needed to avoid severe ecological and economic consequences. The discussion of this presentation focused on

- a potential relationship between PNB and relative yield, particularly in case of PNB=1,
- consideration of gaseous N loss in the calculation of PNB,
- average grain yields in case of a fertilization rate of 40-50 kg N ha^{-1} and the management of N replenishment without negative environmental impacts.

https://ini2021.com/mining-soil-nitrogen-threatens-australian-wheat/

9.7.1.4 Nitrogen management in direct seeded rice, agronomic, physiological and economical perspectives (Hafeez ur Rehman)

Hafeez ur Rehman and co-workers mentioned the poor NUE for rice in Pakistan (< 30%). They studied N uptake by plants in case of different cultivars and different input of fertilizers aiming at optimum conditions.
https://ini2021.com/nitrogen-management-in-direct-seeded-rice-agronomic-physiological-and-economical-perspectives/

9.8 Session 2b – Optimizing the efficiency of nitrogen use in crop production (grain production)

Moderator
Harald Menzi

9.8.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

9.8.1.1 Rice genotypes for higher nitrogen use efficiency in lowlands (Dinesh Kumar)

Dinesh Kumar and his co-workers aimed at higher NUE in rice production in lowlands, because of low efficiency of N fertilizer, i.e. urea, of about ≤ 40% leading to water and air pollution as well as to economic losses. They screened the NUE of ten genotypes of rice under varied rates of fertilizer application in a two-year field study. They found that the genotypes Nidhi, CR Dhan 310 and Nagina 22 were most efficient with respect to grain yields and harvest index.
https://ini2021.com/rice-genotypes-for-higher-nitrogen-use-efficiency-in-lowlands/

9.8.1.2 Information on Seasonal and Varietal Differences Provide Opportunities for Improving Nitrogen Use efficiency and Nitrogen Management in Irrigated Paddy Rice in Kenya (Joseph Gweyi-Onyango)

Joseph Gweyi and his co-workers studied NUE in Sub-Saharan Africa (Kenya), where the situation is characterized by inadequate N fertilizer input compounded with poor soil fertility There is need to synchronize fertilizer application and plant nutrient demand to avoid pollution or nutrient mining. They compared mean N harvest indices, nitrogen agronomic efficiency and NUE of rice varieties as affected by nitrogen rates.
https://ini2021.com/information-on-seasonal-and-varietal-differences-provide-opportunities-for-improving-nitrogen-use-efficiency/

9.8.1.3 Thirty-years long-term rice-rice-rape rotation optimizes 1,2-benzenediol concentration in rhizosphere paddy soil and improves nitrogen use efficiency and rice growth (Xinhua He)

Xinhua He and his co-workers focused on differences in soil metabolites from the rice root rhizosphere and the effects of 1,2-benzenediol on NUE and rice growth in long-term rice-rice-fallow and rice-rice-rape rotations. Crop rotation significantly affected rice rhizosphere metabolites. They found that an optimal soil 1,2-benzenediol concentration under 30-years long-term rice-rice-rape rotation may be associated with an enhanced NUE and root nitrogen uptake and assimilation, resulting in an increased rice growth and yield.
https://ini2021.com/information-on-seasonal-and-varietal-differences/

9.8.1.4 Sustainable nitrogen management in rice cultivation under stress prone areas in Asia (Yam Kanta Gaihre)

Yam Kanta Gaihre and his co-workers compared the effects of urea deep placement (UDP) and broadcast prilled urea (PU) on rice yields, NUE, and economic returns. They performed experiments under drought, submergence and saline conditions in Bangladesh, Nepal and Myanmar. UDP increased grain yields, reduced N losses including nitrous oxide emissions and increased NUE significantly compared to broadcast PU. The results were comparable for all three situations.
https://ini2021.com/sustainable-nitrogen-management-in-rice-cultivation-under-stress-prone-areas-in-asia/

9.8.2 Discussion

All the four recorded presentations were on rice production. Yields from rice production vary considerably between countries and regions depending on natural conditions, available resources, genotypes used etc.

The moderator expressed regret at the low attendance of speakers. There were no questions from the auditory. He concluded that more exchange between the different researches than was possible at this conference would be important for a serious and holistic interpretation of the experimental results in the different countries.

9.9 Session 2b - Optimizing the efficiency of nitrogen use in crop production (technological management) I

Moderator
Tom Bruulsema

9.9.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

9.9.1.1 In-situ real-time NIR monitoring of nitrogen in irrigated cotton northern NSW, Australia (Tim Weaver)

Tim Weaver and his colleagues presented new technical methods for frequent in-crop monitoring. The current agronomic protocol for optimum yield of cotton requires petiole sampling at three critical stages during early crop development. The authors demonstrated that this time-consuming activity can be substituted by handheld near infrared spectrometers (NIRs) in combination with crop models (NutriLOGIC). This system provides in-situ analysis of petioles to address nitrogen deficiencies in real-time. In a field experiment, figures obtained by NIR spectrometry were identical to the conventional analysis.
https://ini2021.com/in-situ-real-time-nir-monitoring-of-nitrogen-in-irrigated-cotton-northern-nsw-australia/

9.9.1.2 Predicting N status in maize with clip sensors: choosing sensor, leaf sampling point, and timing (Jose L. Gabriel)

Jose Gabriel and his co-workers presented a comparison of chlorophyll clip sensors (SPAD-502® and/or Dualex® Scientific). The main goal of these experiments was to determine the ability of the clip sensors to identify the maize N status. Sensors were able to identify maize N status at various crop developmental stages and exhibited comparable results. The authors gave a number of recommendations for the sampling. Finally, clip chlorophyll sensors were able to predict yield and N status, improving prediction accuracy as the crop development progressed.
https://ini2021.com/predicting-n-status-in-maize-with-clip-sensors-choosing-sensor-leaf-sampling-point-and-timing/

9.9.1.3 Sensitivity of hyperspectral bands to N concentration at different growth stages in winter wheat (Jose Luis Pancorbo)

Jose Luis Pancorbo et al. evaluated the estimation of crop N content (%N) by the normalized difference spectral index ($NDSI_{\lambda 1, \lambda 2}$) calculated with all possible two hyperspectral bands at different growth stages in winter wheat. The comparison of canopy spectral reflectance with conventionally analysed %N covered two seasons (winter wheat) with four different N treatments, from non-N-fertilized to over-fertilized, combined with two irrigation levels. %N was determined in wheat samples taken at three growth stages each year: Mid-stem elongation, final stem elongation and flowering. Results obtained with a hand-held VNIR over 325 -1 075 nm with 1 nm spectral resolution were compared to measured %N. The authors recommended $NDSI_{510, 450}$ because of its good correlation with experimental data.
https://ini2021.com/sensitivity-of-hyperspectral-bands-to-n-concentration-at-different-growth-stages-in-winter-wheat/

9.9.1.4 The GxExM interaction and effect on nitrogen uptake in Australian cotton (Tim Weaver)

Tim Weaver et al. also studied the interactions of genetic, environment and management in cotton to improve NUE and yield in cotton systems in Australia. They used the same cultivar in two regions with different climate conditions. N uptake in the whole plant and in stem, leaf and seed were analysed every two weeks starting with the first bloom. Under differing environments and management, the same cultivar was shown to assimilate nitrogen in stem, leaf and seed differently within the plant from first flower to maturity yet produced a similar yield. Further investigation is required to understand the N uptake dynamics in cotton. https://ini2021.com/the-gxexm-interaction-and-effect-on-nitrogen-uptake-in-australian-cotton/

9.9.2 Discussion

There were only a few questions aimed at technical details:

- Which data is used for the calibration of the nutriLOGIC model?
- Can the nutriLOGIC model also be used for other crops?
- Is it possible to determine the water status with NDSI sensors?
- Is there room for machine learning by combining information from several sensors or climate?

9.10 Session 2b – Nitrification & inhibitors; microbes

Moderator
Friedhelm Taube

9.10.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

9.10.1.1 Investigating the fate and behaviour of nitrification inhibitors in soil systems (Parvinder Kaur Sidhu)

Parvinder Kaur Sidhu and her co-workers focused on a deeper understanding of the efficiency, fate and behaviour of nitrogen inhibitors in soil systems through degradation studies. Currently used nitrogen inhibitors have some limitations and their efficiency varies greatly depending upon environmental and edaphic variables. In this study, an effective extraction method for nitrogen inhibitors from soil has been developed, enabling subsequent analysis by HPLC. Degradation products can be identified through isolation and spectroscopic characterisation. First results of soil incubation experiments covering different soil types, variation of pH, temperature and water content demonstrated the applicability of the method to measure inhibition activity and degradation behaviour.
https://ini2021.com/investigating-the-fate-and-behaviour-of-nitrification-inhibitors-in-soil-systems-2/

9.10.1.2 Microbial communities and functional genes of nitrogen cycling in the rhizosphere of rice (B. Ramakrishnan)

B. Ramakrishnan and his colleagues investigated nitrogen-cycling microbial communities in seven different soil types and a tropical rice field by monitoring the abundances of specific gene copies. Additions of nitrogen in the soil microcosms led to typical changes in the abundances of some genes. In the rhizosphere of field-grown rice, the application of N fertilizer or microbial inoculants in combination, the cultivation methods, and the plant growth stages showed characteristic changes. The authors mentioned that rapid detection of changes in nitrogen-cycling microbial communities provides a new option to identify the best management practices.
https://ini2021.com/microbial-communities-and-functional-genes-of-nitrogen-cycling-in-the-rhizosphere-of-rice/

9.10.1.3 The efficacy of 3,4-dimethylpyrazole phosphate on N_2O emissions is linked to niche differentiation of ammonia oxidizing archaea and bacteria across four arable soils (Xiaoping Fan)

Xiaoping Fan et al. aimed at a better understanding of the mechanisms
of the nitrification inhibitor 3,4-dimethylpyrazole phosphate (DMPP) in soils related to both abiotic (soil properties) and biotic factors (ammonia oxidizers and denitrifiers). They found that DMPP effectively inhibited nitrification through inhibiting ammonia oxidizing bacteria (AOB) abundance. Releasing ammonia oxidizing archaea (AOA) from the competition with AOB allowed AOA to efficiently grow and multiply under high ammonium conditions. It turned out that abiotic factors played more important roles than biotic factors in case of N2O emissions from soils. https://ini2021.com/the-efficacy-of-34-dimethylpyrazole-phosphate-on-n2o-emissions-is-linked-to-niche-differentiation/

9.10.1.4 Rhizosphere functional microbiomes drive N availability to wheat (Vadakattu V.S.R. Gupta)

Vadakattu V. S. R. Gupta and his colleagues presented findings on the abundances of N-cycling functional genes in roots and rhizosphere of agronomically adapted wheat varieties varying in root growth, and N uptake efficiency. As rhizosphere and root associated microorganisms regulate the cycling and availability of key macro- (N, P and S) and micronutrients to plants, improved plant-microbe interactions are a more sustainable option for improved yield, NUE, and water efficiency. Significant variation between varieties in microbial functional traits (genes) involved in N availability raises the potential for breeding this trait into modern, elite cultivars of wheat. https://ini2021.com/rhizosphere-functional-microbiomes-drive-n-availability-to-wheat/

10 Theme 3: Ensure health, clean water, air and cities

10.1 Session 3a - Health effects

Moderator
Marijana Ćurčić

10.1.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

10.1.1.1 Reactive nitrogen compounds and their influence on human health (Rolf Nieder)

Rolf Nieder and his colleagues presented the results of an intensive literature study on the impacts of specific nitrogen compounds on human health covering protein deficiency caused by inadequate Nitrogen dietary, impacts of NO_3^- and NO_2^- from drinking water, respiratory diseases due to NO_2 and NH_3. Besides these direct impacts, a high number of indirect effects must be considered, i.e. removal of the greenhouse gas N_2O from the stratosphere via reaction with O_3 thus decreasing the ozone concentration.
https://ini2021.com/reactive-nitrogen-compounds-and-their-influence-on-human-health/

10.1.1.2 Particulate organic nitrogen at an agricultural region in South Africa (Pieter Van Zyl)

Pieter Gideon van Zyl characterised organic nitrogen compounds in atmospheric aerosols collected in an agricultural region. The research group detected 135 compounds, mostly amines (51%), but also nitriles (20%), pyridine derivatives (11%), and amides (8%). Anthropogenic urban emissions and regional agricultural activities were considered as the major sources of organic N species. With respect to this study, the necessity for speciation of N compounds in relation to health impacts is clearly seen.
https://ini2021.com/particulate-organic-nitrogen-at-an-agricultural-region-in-south-africa/

10.1.1.3 Projecting future nitrogen pathways and their impacts: the GLOBIOM-GAINS framework (Wilfried Winiwarter)

Wilfried Winiwarter introduced the coupling of the partial equilibrium model GLOBIOM with the GAINS-model, a pollution and impact model to provide quantified projections of future reactive nitrogen pollution. This is a global model with high resolution, i.e. the impact of nitrogen pollution on human health in specific cities can be calculated. With this approach, effects of different climate scenarios can be distinguished. Moreover, efficiency of air pollution measures can be assessed.
https://ini2021.com/projecting-future-nitrogen-pathways-and-their-impacts-the-globiom-gains-framework/

10.1.2 Discussion

In the panel discussion, the presenters concluded that their actual results are some type of milestones in their research allowing a clear direction of further research. Mutual collaboration is possible. All of them agreed that human health impacts by reactive nitrogen (N_r) is proven. They advised to calculate the financial consequences of health effects (e.g. money needed for treatment of diseases) as a powerful tool in negotiation with regulators and industry ("money talks").

10.2 Session 3b - Reduction of nitrogen in wastewater to ensure clean water and sanitation

Moderator
Stefanie Wolter

10.2.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

10.2.1.1 Assessing nitrogen fluxes: From human food intake over urine and faeces to wastewater treatment and disposal (Ina Koerner)

Ina Koerner and her colleague focused on recovery of nitrogen from wastewater. As > 99% of N that is ingested by food and drinks is excreted, an enormous share of N_r can be recovered from waste water. Together with her co-author, Ina presented several options for N valorization to avoid either emission of NH_3 from untreated wastewater or loss of N from state of the art purification processes. The discussion focused on traditional processes like collection of excrements and compost toilets and problems arising with persistent pharmaceuticals.
https://ini2021.com/assessing-nitrogen-fluxes-from-human-food-intake-over-urine-and-faeces/

10.2.1.2 Reducing nitrogen pollution in water systems in China: implications for the Sustainable Development Goals (Mengru Wang)

Mengru Wang et al. studied N_r pollution of Chinese rivers and their development until 2050. They concluded that China will probably not meet SDGs 6 and 14 until 2050. Improved nutrient management in agriculture and in sewage systems, efficient food consumption and climate mitigation are necessary to reach the goals. They identified >300 interactions between water-related SDGs. 90% of them with synergy effects and 10% with trade-offs.
https://ini2021.com/reducing-nitrogen-pollution-in-water-systems-in-china/

10.2.1.3 Global Accounting of Reactive Nitrogen in Municipal Solid Waste (David Meng-Chuen Chen)

David Meng-Chuen Chen and his co-workers estimated stocks and flows of N_r of waste in landfills and dumps which represent the by far most important disposal method. Based on this data, using carbon and nitrogen degradation processes leading to N_2O emissions, they assessed a stock of about 302 Mt N_r (2050) in waste. Only 10% of N_r deposited is mobilized yearly. The discussion focused on mitigation by separation of waste at source.
https://ini2021.com/global-accounting-of-reactive-nitrogen-in-municipal-solid-waste/

10.2.1.4 Regional nitrogen soil surface budgets Germany (Uwe Häußermann)

Uwe Häußermann and his co-workers presented figures from Germany focusing on regional N soil surface budgets that vary between 26 and 162 kg N ha^{-1} yr^{-1}. The N surplus in the districts is closely related to the livestock number. Due to German legislation, manure is transferred to arable farming regions with low N surplus. But the national balance (mean value about 77 kg N) varied only slightly. Measures to reduce the increasing nutrient surplus from biogas production in areas with high livestock density were discussed.
https://ini2021.com/regional-nitrogen-soil-surface-budgets-germany/

10.2.1.5 The Nitrogen Legacy: Long-term effects of water pollution on human capital (Esha Zaveri)

Esha Zaveri et al. interpreted health statistics with respect to nitrate concentrations in drinking water. They found that nitrogen exposure experienced by infants can have durable, long-term impacts that stretch well into adulthood. According to their investigation, Indian women are shorter on average if they were exposed to high nitrate concentrations in their first three years of life. In the discussion, the question was raised whether other factors such as malnutrition could be excluded.
https://ini2021.com/the-nitrogen-legacy-long-term-effects-of-water-pollution-on-human-capital-2/

11 Theme 4: Combat threats for biodiversity

11.1 Session 4a - Threats for terrestrial biodiversity I

Moderator
Markus Geupel

11.1.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

11.1.1.1 Towards critical levels for ammonia - a fumigation study using endangered nitrogen sensitive plant species (Jürgen Franzaring)

Jürgen Franzaring and his co-workers studied chronic phytotoxic properties of low NO_2 concentrations. They exposed a number of rare and protected Central European plant in greenhouse compartments over two seasons.
https://ini2021.com/towards-critical-levels-for-ammonia-a-fumigation-study/

11.1.1.2 Critical Nitrogen Loads in nitrogen-sensitive Forest Associations - Results from Baden-Württemberg, south-western Germany (Marina Roth)

Marina Roth and her colleagues focused on correlations between soil nitrogen content and changes in the understory vegetation of nitrogen-sensitive temperate forests aiming at specific load limits for reactive N compounds. There was a question from the audience to estimate critical loads for the observed forest types.
https://ini2021.com/critical-nitrogen-loads-in-nitrogen-sensitive-forest-associations/

11.1.1.3 Mapping potential future developments of forests due to climatic change and nitrogen deposition (Winfried Schröder)

Winfried Schröder presented expected changes of forest ecosystems, that were generated by dynamic modelling of soil science indicators considering climate change and anthropogenic nitrogen inputs for the periods until 2040 and 2070. Calibration of the indicators based on reference conditions in the 20th century and their development until 2011.
https://ini2021.com/mapping-potential-future-developments-of-forest-ecosystems-due-to-climate-change/

11.1.1.4 Dose-effect Relations for Habitat types and Nitrogen deposition (Wieger Wamelink)

Wieger Wamelink and co-workers assessed the vulnerability of ecosystems towards nitrogen deposition. They focused on the species composition changing with increasing nitrogen deposition also below the “critical load”. Potential over-estimation of existing critical loads and their role in legislative approaches were discussed.
https://ini2021.com/dose-effect-relations-for-habitat-types-and-nitrogen-deposition/

11.1.1.5 Nitrogen budget and critical load estimate in a semi-arid grazed ecosystem (Claire Delon)

Claire Delon et al. calculated a nitrogen budget in a semi-arid grazed ecosystem in Senegal, including nitrogen inputs and outputs (natural and man-made). Calculated nitrogen inputs did not exceed the critical load estimated for this specific ecosystem. This study showed a first attempt to quantify the nitrogen budget of a sandy-soil ecosystem and to propose a critical load based on these budgeting. It was discussed that these promising results were unique for this region of the African continent and that more of such research is needed.
https://ini2021.com/nitrogen-budget-and-critical-load-estimate-in-a-semi-arid-grazed-ecosystem/

11.1.1.6 Impacts of invasive plants on Nitrogen cycling in a montane tropical grassland (Manaswi Raghurama)

Manaswi Raghurama investigated (together with Mahesh Sankaran) how N-fixing invasive plant species change nutrient cycling in soils of an Indian biodiversity hotspot. This was an interesting and new approach to the attendees of the session. With this approach the authors showed an example that even unwanted accelerated biological nitrogen fixation through invasive plant species alters nitrogen flows in and between ecosystems substantially.
https://ini2021.com/impacts-of-invasive-plants-on-nitrogen-cycling-in-a-montane-tropical-grassland/

11.1.2 Moderator's summary

In this session six presentations were given, dealing with atmospheric nitrogen inputs into terrestrial ecosystems and the assessment of related negative effects. Three of the presentations showed results of studies in Germany, the other ones brought up results from studies in India, the Netherlands and Senegal respectively. Although the six talks were framed correctly under the same headline of the session, in detail the spectrum of the presentation was diverse and independently: nearly all of the contributions were dealing with different subjects.

In total, in the presentations three different environmental effects related to different forms of nitrogen were presented: direct toxic effects of atmospheric ammonia, nitrogen deposition and resulting eutrophication of ecosystems and elevated nitrogen fixation rates through invasive plant species and resulting nitrate.

Three presentations showed different approaches to derive an estimation of critical loads. Approaches reach from very sophisticated methods to assess impacts into highly protected nature areas in the Netherlands to more simple approaches in Senegal to give a first estimation of ecosystem sensitivity. Especially for the assessment of nitrogen deposition with critical loads in the context of legislative processes, which is often the case in Europe, the robustness of the calculated critical load is of high importance.

Last but not least it was underlined that direct effects of ammonia on plants may play an important role and that experimental studies to assess and quantify such effects are a useful element to increase robustness of critical levels.

11.2 Session 4a - Threats for terrestrial biodiversity II

Moderator
Henning Meesenburg

11.2.1 Presentations:

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

11.2.1.1 Nitrogen availability along an elevational transect in a tropical montane forest - Rwenzori, Uganda (Joseph Okello)

Joseph Okello and his co-workers demonstrated that the closure of the N cycle in tropical montane forests is more effective with increasing elevation. Whereas soil N concentration decreased three-fold along the elevation transect, canopy N content showed negative correlation with elevation with linear decrease of 0.1% per 100 m of elevation increase. Meanwhile, canopy N:P ratio revealed more N availability at the lowest elevation and more P availability at higher elevations. The results support the paradigm of shifting nutrient limitation from P to N when transiting from low land to montane forest.
https://ini2021.com/nitrogen-availability-along-an-elevational-transect-in-a-tropical-montane-forest-rwenzori-uganda/

11.2.1.2 Nitrogen oligotrophication in forests: An emerging global trend? (Peter Groffman)

Peter Groffman reminded of numerous scientific works on N deleterious effects of excess N on forests. Recent declines in atmospheric nitrogen (N) deposition and in N export from these ecosystems have raised concerns about N oligotrophication leading to limitations of forest productivity and resilience against environmental stresses. He presented some results of recent investigations and suggested to re-evaluate the nature and extent of N cycling in forests and assess how changing conditions will influence
https://ini2021.com/nitrogen-oligotrophication-in-forests-an-emerging-global-trend/

11.2.1.3 Impacts of nitrogen deposition on forest mineral -soil biogeochemical processes, across a trans-European gradient, investigated using a tool kit of stable isotope methods (Rebecca Hood-Nowotny)

Rebecca Hood-Nowotny and her co-workers presented a study across a European climate gradient over two years. The group measured the impact of simulated atmospheric nitrogen deposition, on forest soil carbon sequestration and examined the consequences for ecosystem function. They traced the isotopic and molecular pathways through the microbial biomass and investigated the concurrent biogeochemical processes as they happened in the field.
https://ini2021.com/impacts-of-nitrogen-deposition-on-forest-mineral/

11.2.1.4 Nitrogen deposition increases drought sensitivity in Swiss forests (Sabine Braun)

Sabine Braun and her co-workers studied growth trends and mortality of European beech and Norway spruce in relation to N deposition varying between 8 and 81 kg N ha^{-1} yr^{-1}. They found a strong increase of drought susceptibility under high N deposition.
https://ini2021.com/nitrogen-deposition-increases-drought-sensitivity-in-swiss-forests/

11.2.1.5 Accumulation of Atmospheric Nitrogen Deposition in Mosses (Winfried Schröder)

Winfried Schröder and his colleague found that mosses are an excellent indicator for the accumulation of atmospheric substance inputs in large areas. Winfried Schröder and Stefan Nickel presented an evaluation of the European Moss Survey back to 1990 covering more than 7,000 sites in 34 countries. In contrary to many heavy metals there is decrease in bioaccumulation of N compounds.
https://ini2021.com/accumulation-of-atmospheric-nitrogen-deposition-in-mosses/

11.2.2 Discussion

Participants asked for more studies to investigate the effects of N deposition on forest ecosystems under different N deposition levels, particularly more monitoring data also for the biodiversity, and the coupling of climate change and N effects on forest ecosystems. This is particularly interesting in case of tropical forests due to their enormous biodiversity. The potential increase of drought effects under high N deposition needs more research. There was a controversial debate, as to whether oligotrophication is a threat for temperate forest ecosystems.

11.3 Session 4b - Threats for aquatic biodiversity (inland)

Moderator
Frank Hilliges

11.3.1 Presentations:

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

11.3.1.1 Excessive N inputs elevate nitrate concentrations of shallow and deep well groundwater along the Indus River floodplain aquifer in Pakistan (Muhammad Riaz)

Muhammad Riaz and co-workers from Pakistan analysed ground water samples in the Indus basin This is an area with intensive agriculture and excessive use of nitrogenous fertilizers leading to nitrate contamination of surface and groundwater. Contaminations were not only found in shallow but also in deep groundwater wells. Nitrate concentrations of shallow wells were below 50 mg l^{-1} during the start and middle of dry season, respectively, but increased at the end of the dry season (70% of both shallow and deep wells samples > 50 mg l^{-1}).
https://ini2021.com/excessive-n-inputs-elevate-nitrate-concentrations-of-shallow-and-deep-well-groundwater/

11.3.1.2 High-resolution simulation of nitrate leaching from agricultural land across Germany (Claas Nendel)

Claas Nendel and his colleagues investigated the connection between observed nitrate concentrations in wells across Germany and agricultural management. They used an mechanistic agro-ecosystem simulation model on a high-performance cluster computer to simulate crop growth, management and resulting nitrate leaching on a hectare scale.
https://ini2021.com/high-resolution-simulation-of-nitrate-leaching-from-agricultural-land-across-germany/

11.3.1.3 Mapping nitrate concentrations in upper groundwater using Random Forest (Job Spijker)

Job Spijker and co-workers created a map of nitrate concentrations leaching from the root zone of Dutch agricultural soils. The authors used nitrate data from a national monitoring network and the Random Forest algorithm as prediction and interpolation method. A large set of spatial auxiliary data, like soil types, groundwater levels and crop types, was used as dependent variables. The explained variance and statistical errors indicated that the interpolation and map visualisation is suitable for interpretation of the spatial variability of the nitrate concentrations in the Netherlands.
https://ini2021.com/mapping-nitrate-concentrations-in-upper-groundwater-using-random-forest/

11.3.1.4 Sources of nitrogen in rivers worldwide: exploring linkages to sustainable development goals (Maryna Strokal)

Maryna Strokal and her co-workers from Germany and the Netherlands analysed sources of total dissolved N (TDN) in rivers worldwide. They used suitable model calculations for point and diffuse source to calculate TDN for more than 10,000 river basins and sub-basins. They concluded that more than 50% of the total load of 110 Tg TDN yr^{-1} is caused by diffuse anthropogenic sources. The results can be used to link sustainable development goals (SDGs) and pollution sources.
https://ini2021.com/sources-of-nitrogen-in-rivers-worldwide/

11.3.1.5 Precising target NO_3^- concentrations to limit green algae blooms in Brittany (Durand Patrick)

Patrick Durand and his colleagues investigated the roots of Green macroalgae blooms in the French region Brittany. Problems with coastal eutrophication mostly come up with N inputs by rivers. Former studies recommended a target nitrate water concentration around 2.5 mg l^{-1} in the streams to avoid algae blooms. Though the concentrations did not meet this target up to now, bloom limitations occurred recently, under specific climatic conditions. Coupling the ecological model MARS-ULVES with the agro-hydrological model TNT2 allowed testing contrasted climate sequences and precising the target concentrations for future policy.
https://ini2021.com/precising-target-no3-concentrations-to-limit-green-algae-blooms-in-brittany/

11.3.1.6 Discussion report by the moderator

The central topic of almost all presentations was the input of nitrate into water. Most presentations of this session focused on the modelling of nitrate inputs into the environment on different spatial levels. All speakers pointed out that the consideration of substance inputs in environmental systems must always take place in the context of a holistic system approach and should not be understood as a singular process. The speakers also pointed out the limiting boundary conditions in the modelling, e.g. poor quality of the input data or methodological weaknesses in the statistical procedures used. Some important new aspects presented covered

- the approaches to modelling (C. Nendel et al., J. Spijker)
- and the use of worldwide data sets for a global view of the nitrogen situation in rivers (M. Strokal).

The “Random Forest modelling” presented by J. Spijker was particularly a very interesting and innovative approach of calculating nitrate distributions in groundwater. Durand and co-workers demonstrated how a combination of an ecological with an agro-hydrological model can be used to specify targets for N concentrations in coastal waters with the aim of preventing algal blooms.

The discussion showed that the validation of the models plays an important role. In particular, the availability of real measurement data with a high temporal and spatial resolution is of great importance. The availability of agricultural data on land use is problematic.

The work on models has to be continued aiming at an improvement of the predictability. Better data on each temporal and spatial scale are necessary for validation.

Furthermore, the moderator stated that the "Random Forest approach" presented by J. Spijker is used in a similar form in Germany (Bach, University of Giessen). Both approaches were developed and published independently of one another. The two research groups were brought into contact with each other.

11.4 Session 4b - Threats for aquatic biodiversity (offshore)

Moderator
Simone Richter

11.4.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

11.4.1.1 Nitrogen, Water and Global Change - an Integrated Modelling Perspective (Carolien Kroeze)

Carolien Kroeze and her colleagues from the Netherlands and China presented approaches to model nitrogen and water under global change. They focused on integrated model systems that cover causes, effects and solutions of nitrogen pollution in different aquatic systems, i.e. rivers, lakes, groundwater and coastal seas. How will global change influence future water quality and water quantity, and the availability of clean water for nature and society? She concluded that there is an urgent need for models that integrate water, nutrient and crops while accounting for socio-economic drivers, impacts of climate change and other global trends and the effectiveness of solutions.
https://ini2021.com/nitrogen-water-and-global-change-an-integrated-modeling-perspective/

11.4.1.2 Effects of vegetation structure on nutrient outflows from a montane tropical Forest-Grassland mosaic (Manaswi Raghurama)

Manaswi Raghurama and his co-workers studied the impacts three invasive N-fixing woody plant species on the nutrient outflow from the Nilgiri region, a biodiversity hotspot in the Western Ghats, India. They determined sediment and nutrient outflows from 11 catchments with different proportions of forests, grasslands and invasive species. They found that invasion into grasslands is increasing soil erosion and nutrient outflows. This was also found in the case of cloud forests though the invasive species are woody structures.
https://ini2021.com/effects-of-vegetation-structure-on-nutrient-outflows-from-a-montane-tropical-forestgrassland-mosaic/

11.4.1.3 Geographical targeted landscape management for reduced N pollution from agriculture (Tommy Dalgaard)

Tommy Dalgaard discussed geographically targeted management of agricultural landscapes as a key to achieve ambitious reduction targets for water, air and climate pollution. This is of special interest in case of more targeted regulation to supplement existing general regulation of nitrogen use and management as it is the case in Europe. Targeted regulation aims at changed crops and crop rotations dependent on landscape properties, better distribution of livestock manure and fodder, management of livestock facilities and introduction of new biotopes for reduced pollution from agriculture in the landscape. Geographically targeted landscape management to reduce N pollution is now possible based on the development of new 3D digital mapping and complex modelling techniques.
https://ini2021.com/geographical-targeted-landscape-management-for-reduced-n-pollution-from-agriculture/

11.4.1.4 Nitrogen impacts on the Wadden Sea and adjacent Elbe Estuary (Europe): ecosystem degradation, recovery and ongoing impacts (Justus van Beusekom)

Justus van Beusekom and his team from the Helmholtz Center Geesthacht gave an overview about the development of eutrophication and countermeasures in the Wadden Sea, a shallow tidal sea along the European north-western continent. Measures to reduce riverine nutrient loads improved the ecological status of the Wadden Sea considerably. But eutrophication is still a major problem in the adjacent Elbe estuary. Massive phytoplankton blooms from the Elbe river lead to low oxygen concentrations in the dredged part of the tidal Elbe in the vicinity of the Hamburg harbour. An automated observation system is under construction aiming at a quantitative analysis of the flows of C, N, P and some metals in the estuary to understand the transformation processes.
https://ini2021.com/nitrogen-impacts-on-the-wadden-sea-and-adjacent-elbe-estuary-europe/

11.4.1.5 Reducing nutrient pressures on aquatic ecosystems in Europe (Bruna Grizzetti)

Bruna Grizzetti and her colleagues presented an overview on sources of N and P and their impacts on coastal areas around Europe. They assessed the potential improvement on the ecological status of aquatic ecosystems based on current European legislation, i.e. the Rural Development Plans, supported by the EU Common Agricultural Policy and developed two more scenarios, one covering the full implementation of the Urban Waste Water Directive and another one taking into account maximum technical feasibility in the reduction of nutrients, using best technologies in wastewater treatment and decreasing mineral fertilisers application in agriculture. Current policy will decrease the nutrient export to seas by 14% for N and 20% for P. She concluded that the reductions might not be sufficient for achieving the goals of EU water policy in some regions without tackling present agricultural production and consumption systems.
https://ini2021.com/reducing-nutrient-pressures-on-aquatic-ecosystems-in-europe/

11.4.2 Discussion

There was a lively discussion covering the following topics:

- Nitrogen, water, and global change: It was stated that N loads are not the best indicators for coastal ecosystems, instead a combination of several factors was mentioned. Which factors have been used in which combination?
- Impacts of invasive plant on N losses: What are the sources of P and what are the long-term implications of an enhanced export of P?
- Geographical targeted landscape management: As mentioned in the presentation, subsurface redox zones and wetlands are important areas to remove N by denitrification. On the other hand, redox zones release P that can e.g. fix N by cyanobacteria in the Baltic. How the interaction between N and P is considered in the model?
- Nitrogen impacts on the Wadden Sea: To what extent would the nitrate input have to be reduced in order to achieve a "good ecological status"? Is it possible to define a threshold level?
- Nutrients in European aquatic ecosystems: Which measures are most likely to reach the EU water policy goals? And which EU regions need the highest reduction?

12 Theme 5: Observing global challenges, fluxes and interactions between different drivers and pressures

12.1 Session 5a – Climate feedbacks including N_2O emissions

Moderators
Bernhard Osterburg and Christian Brümmer

12.1.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

12.1.1.1 Impact of nitrogen additions on greenhouse gases emissions at different stages of plant residue decomposition (Muhammad Sanaullah)

Muhammad Sanaullah and his co-workers studied the impact of N addition at different stages of plant residue decomposition and residue type (wheat and rice) on CO_2 emissions and soil health parameters in the laboratory. In case of the addition of nitrogen (132 mg kg^{-1}) significant increase in cumulative C-CO_2 as well as of microbial biomass was observed. Similarly, enzyme activities also enhanced with the addition of crop residues but there was significant decrease in chitinase activity with the addition of wheat residues, whereas rice residues significantly enhanced all enzymes activity except acid phosphatase.
https://ini2021.com/impact-of-nitrogen-additions-on-greenhouse-gases-emissions/

12.1.1.2 The Global N_2O Database - Open & collaborative science for addressing epic N_2O issues (Chris Dorich)

Christopher Dorich and colleagues from the U.S., Australia, Germany, Denmark, the UK, and New Zealand presented a framework to fill in the gaps of N_2O measurements. N_2O concentrations are notoriously variable through time, across space, and with management and environmental conditions. Therefore, gaps lead to uncertainties and hamper the development of mitigation measures. Their framework ("Global N_2O Database") allows for consolidation and compatibility of data sets, which can serve as a catalyst for methods improvement, improved process understanding and emissions estimates, and model improvement within the N_2O field.
https://ini2021.com/the-global-n2o-database-open-collaborative-science-for-addressing-epic-n2o-issues/

12.1.1.3 Effect of crop residue management on N_2O emissions in European cropping systems (Marco Carozzi)

Marco Carozzi and his co-workers studied the influence of crop residue management on N_2O emissions. Four different scenarios were evaluated in detail in European cropping systems with two biogeochemical models. They found that recycling of crop residues into soils increases crop yields and also raises the carbon stocks, but leads to higher N_2O emissions in the long run. Therefore, the benefits of this management is limited to some decades, because elevated N_2O emissions offset CO_2 sequestration ("4 promille initiative"). Interestingly, the emission factor from crop residues are expected to be lower than the IPCC standard.
https://ini202 1.com/effect-of-crop-residue-management-on-n2o-emissions-in-european-cropping-systems/

12.1.1.4 Food security and greenhouse gas emissions for cereals in sub-Saharan Africa towards 2050 (Martin van Ittersum)

Martin van Ittersum and colleagues from the Netherlands, Ethiopia and Tansania assessed the increase in cereal demand and associated greenhouse gas (GHG) emissions for ten countries in sub-Saharan Africa in 2050, based on different scenarios of intensification and cropland expansion. The authors concluded that cereal self-sufficiency in sub-Saharan Africa is possible with current cereal area, but only just so. Current yields of ca. 20% of yield potential will have to increase to ca. 80% of the potential, which requires an unprecedented steep and continuous increase in production for rain-fed systems. Gains depend on the level of NUE achieved. GHG emissions increase by about 50% in case of intensification, but would increase five- to six-fold with current yield trends and NUE values.
https://ini2021.com/food-security-and-greenhouse-gas-emissions-for-cereals-in-sub-saharan-africa-towards-2050/

12.1.1.5 Long-term trajectories of the carbon footprint of nitrogen use in Mediterranean agriculture (Spain, 1860-2016) (Eduardo Aguilera)

Eduardo Aguilera and his co-workers assessed the carbon footprint of N use in Spanish agriculture from 1860 to 2016, including emissions from industrial fertilizer production, direct soil N_2O emissions using Mediterranean-specific factors, and indirect N_2O emissions. Overall, the yield-scaled carbon footprint of N use in Spanish agriculture increased threefold, as increased productivity and industrial energy efficiency could not offset the growth in synthetic N use and in N_2O emission. The authors concluded that mitigation efforts under Mediterranean climate should not only aim to increase NUE but also consider water management, fertilizer manufacture and fertilization strategies as key drivers of emissions.
https://ini2021.com/long-term-trajectories-of-the-carbon-footprint-of-nitrogen-use-in-mediterranean-agriculture/

12.1.1.6 Impact of fertilizer additives on N_2O emissions for contrasting corn growing seasons in Canada (Elizabeth Pattey)

Elizabeth Pattey and her colleagues investigated the N_2O emissions of a corn field due to fertilization in a side-by-side corn field-scale experiment over two growing seasons. Two areas of the field were fertilized with urea; in another section of the field urease and nitrification inhibitors were added. For both years, the yield was slightly lower where inhibitors were used. The cumulative N_2O emissions for the season was 4.7 kg N_2O-N ha^{-1} for the area fertilized with urea only and 25% lower for the area treated with inhibitors. The seasonal N_2O emission reductions caused by the inhibitors differed considerably depending on the climate.
https://ini2021.com/impact-of-fertilizer-additives-on-n2o-emissions-for-contrasting-corn-growing-seasons-in-canada/

12.1.1.7 Inventory reporting of livestock emissions: the impact of the IPCC 1996 and 2006 Guidelines (Gültac Cinar)

Gültac Cinar presented effects of the IPCC methodologies (guidelines of 1996 and 2006) on estimates of GHG emissions from the livestock sector. The authors used Austria as a case study. It was demonstrated that there were prominent changes in livestock GHG emissions from different source categories depending on the methodology. The authors concluded that there is a strong relationship between emission inventory methodology and mitigation options as the mitigation measures will only be effective for meeting emission reduction targets if their effectiveness can be demonstrated. Therefore, the improvement of future inventories must include the gathering of high resolution data and accurate, country-specific emission factors. https://ini2021.com/inventory-reporting-of-livestock-emissions-the-impact-of-the-ipcc-1996-and-2006-guidelines/

12.2 Session 5b - Biogeochemical N Cycle (ammonia / deposition)

Moderator
Wilfried Winiwarter

12.2.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

12.2.1.1 Standing on the shoulders of giants - Research infrastructures as modular platforms for reactive nitrogen deposition monitoring (Frederik Schrader)

Frederik Schrader recommended the use of existing monitoring and infrastructure for greenhouse gases for monitoring reactive nitrogen compounds. The monitoring stations in place can be readily equipped with the necessary instrumentation to estimate N_r (dry deposition) or to measure total N_r.
https://ini2021.com/research-infrastructures-as-modular-platforms-for-reactive-nitrogen-deposition-monitoring/

12.2.1.2 Modelling Nitrogen Deposition in Germany from 2000-2015 (Martijn Schaap)

Martijn Schaap and his co-workers modelled total nitrogen deposition over a period of 16 years. Resulting deposition data are available on a 1x1 km^2 grid for Germany covering oxidized, reduced and total inorganic nitrogen compounds. Deposition in Germany has decreased from above 649 Gg N yr^{-1} (2000) to 529 Gf N yr^{-1} (2015).
https://ini2021.com/modelling-nitrogen-deposition-in-germany-from-2000-2015/

12.2.1.3 Modelling Atmospheric Ammonia using Agricultural Emissions with Improved Spatial Variability and Temporal Dynamics (Xinrui Ge)

Xinrui Ge and her co-workers improved an existing ammonia emission model that quantifies agricultural emissions in Germany and Benelux.
https://ini2021.com/modelling-atmospheric-ammonia-using-agricultural-emissions-with-improved-spatial-variability/

12.2.1.4 Satellite monitoring of ammonia: from point sources to long-term trends (Martin Van Damme)

Martin van Damme and his colleagues used satellite NH_3 measurements to identify, categorise and quantify emission hotspots. They were able to track-down more than 500 localized point sources of agricultural origin and from industrial fertilizer, coking, soda ash, geothermal and explosives production as well as from natural origin. They concluded that point sources are massively underestimated in bottom-up inventories.
https://ini2021.com/satellite-monitoring-of-ammonia-from-point-sources-to-long-term-trends/

12.2.1.5 Top-down estimation of NH_3 emissions and related deposition in LOTOS-EUROS using an Ensemble-Kalman approach (S. C. van der Graaf)

S.C. van der Graaf et al. also used satellite data. They demonstrated discrepancies with existing models on the basis of global daily NH_3 column measurements.

https://ini2021.com/top-down-estimation-of-nh3-emissions-and-related-deposition-in-lotos-euros/

12.2.1.6 The dynamics of ammonia bi-directional exchange above agricultural crops (Alexander Moravek)

Alexander Moravek and his co-workers aimed at a better understanding of NH_3 bi-directional exchange in agricultural ecosystems. They studied NH_3 fluxes above a corn field over two growing seasons. They concluded that the canopy is rather important for regulating net NH_3 exchange.
https://ini2021.com/the-dynamics-of-ammonia-bi-directional-exchange-above-agricultural-crops/

12.2.2 Discussion

The moderator highlighted the following results:

Great improvements have been made in quantifying ammonia deposition, with a majority of study sites shown situated in Northwest Europe (Belgium, Germany, the Netherlands). One approach uses the eddy covariance technique, which can be extended to cover NH_3 even when established for other purposes (CO_2) and allows also to quantify soil sinks. Another approach is based on satellite measurements (IASI and CrIS). While not directly providing deposition, atmospheric concentrations at high spatial resolution can be derived to identify point sources (industry, animal feedlots), and a temporal trend of ongoing increase can be established. Moreover, satellite information can improve spatial and temporal patterns of emissions, also together with using other sources. This allows to further improve atmospheric modelling, and more adequately quantify atmospheric removal pathways for ammonia as a gas or in particulate matter.

According to Winfried Winiwarter, these subjects need further research:

- If fertilized soils not only act as NH_3 sources, but also as sinks, that would influence the net emission factors e.g. of fertilizer application. This implies
    - (i) there must be a nearby source leading to atmospheric concentrations much higher than produced from the soil – which needs to be identified, and (ii) there is a possibility that part of the emissions are deposited / removed swiftly such that they are better not accounted for in typical atmospheric models (with 1 x 1 km^2 grid cells) – which share would that part be?
- Atmospheric models with a bi-directional NH_3 exchange scheme need an improved representation of soil, stomatal and cuticular emissions potentials due to their high spatial and temporal variability – how would such a representation look like?
- In-situ N_r deposition monitoring can be performed based on a network of many low-cost measurements for individual compounds, or by few selected total N_r deposition sites. What is the best compromise between accurate model calibration and practicability?
- IASI and CrIS NH_3 satellite datasets are based on different retrieval strategies, which necessitate different approaches in their exploitation. In addition, further work is needed on comparing and harmonizing datasets to maximize their scientific return.
- Despite of efforts to reduce NH_3 emissions, atmospheric concentrations have been observed to continuously increase (2-4% per year over Europe, 6% per year over China). Is this just an effect of atmospheric chemistry (lower $SO_2$and NO_x emissions, decreased

formation of particulate matter (PM) allowing more NH_3 to remain in the atmosphere) or would we need to assume also emissions have been increasing? How would we be able to find out?

- Which effects of a changing atmosphere (global temperature and precipitation patterns, concentrations of other compounds) are influencing NH_3 and also abatement efforts? Specifically, which conditions will favour removal pathways (as NH_3 gas or as PM) and redistribute impacts to vegetation or to human health?

12.3 Session 5b – Biogeochemical N Cycle (N_2O, denitrification, water)

Moderator
Benjamin Bodirsky

12.3.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

12.3.1.1 Hydrological N export from tropical forests in the Congo Basin (Simon Baumgartner)

Simon Baumgartner and his co-workers from the Democratic Republic of Congo, Switzerland and Belgium studied the N balance of tropical forests in the Congo Basin. Tropical forests play an important role in the global carbon cycle and represent a significant CO_2 sink. Maintaining this function requires a large and sustained availability of N. However, the mechanism of N losses is not clear. They monitored headwater streams draining three different forest types measuring particulate and dissolved N and P export with a particular focus on storm events. They found that particulate N loss (particulate organic N) is of major importance for the balance. Furthermore, N losses via soil erosion were detected.
https://ini2021.com/hydrological-n-export-from-tropical-forests-in-the-congo-basin-2/

12.3.1.2 Integrated control and Modelling of Denitrification in Agricultural Soils at various scales (DASIM) - first data sets for model evaluation (Reinhard Well)

Reinhard Well and colleagues from numerous research institutions presented a model designed for the quantitative prediction of denitrification rates as a function of microscale soil structure, organic matter quality, DRPs and atmospheric boundary conditions. Data for the validation were obtained by combining state-of-the-art experimental and analytical tools (X-ray µCT, 15N and 18O tracing, isotopomers, NanoSIMS, micro-sensors, advanced flux detection, NMR spectroscopy, and molecular methods including next generation sequencing of functional gene transcripts). The results available so far show satisfactory agreement between measured and predicted denitrification rates. The project will be continued.
https://ini2021.com/integrated-control-and-modelling-of-denitrification/

12.3.1.3 Managing reactive nitrogen in agricultural systems under future conditions in Austria (Bano Mehdi-Schulz)

Bano Mehdi-Schulz and her colleagues presented the Austrian NitroClimAT project. The project will provide a cost estimate of agricultural management strategies for agricultural systems that minimize N_r losses to surface water bodies and to the atmosphere under future climate and future socio-economic and policy scenarios. In the on-going project, N_r emissions are tracked, starting with the inputs into cropping systems and simulates them through the flow paths in agricultural and water systems. The framework consists of a biophysical crop model, an economic land use model, a substance transport model, and an eco-hydrological model. She presented results on NUE and nitrate leaching.
https://ini2021.com/managing-reactive-nitrogen-in-agricultural-systems-under-future-conditions-in-austria/

12.3.1.4 Quantifying landscape-level annual nitrous oxide fluxes in the Tibetan Plateau (Lei Ma)

Lei Ma and his colleagues measured two-year N_2O fluxes and environmental variables from a typical landscape in the Tibetan Plateau. Long-term measurements are necessary to better understand the N_2O fluxes feedbacks to changing climate, particularly in climate-sensitive areas like Tibet. Annual N_2O emissions showed large spatial variations (0.05–0.78 kg N ha^{-1} yr^{1} from meadows to forest) which was significantly ($p < 0.01$) controlled by soil carbon-to-nitrogen ratios and dissolved organic carbon concentrations. Results also highlighted the importance of the non-growing seasons (particularly soil freeze-thaw periods) as they contributed 12–57% to annual fluxes.
https://ini2021.com/quantifying-landscape-level-annual-nitrous-oxide-fluxes-in-the-tibetan-plateau/

12.3.1.5 Terrestrial denitrification and nitrous oxide emissions: global estimates and uncertainties (David E. Pelster)

David E. Pelster from Canada and his German colleagues also contributed to better estimates of denitrification. They compared global terrestrial denitrification rates estimated using measured N_2:N_2O product ratios with rates estimated using an N mass balance and with previous published studies. They also summarised datasets that measured field N_2O:(N_2O+N_2) product ratios and used this to infer global denitrification using estimates of global terrestrial N_2O flux. They concluded that terrestrial N_r has more than doubled during the last 100 years. They assessed the global denitrification rate ranging between 115 and 202 Tg N yr^{-1}; terrestrial denitrification doubled since pre-industrial times removing 56% of new N_r each year.
https://ini2021.com/terrestrial-denitrification-and-nitrous-oxide-emissions-global-estimates-and-uncertainties/

12.3.1.6 The use of nitrogen compounds from organic waste (Daniel Pleissner)

Daniel Pleissner presented experiments with food waste aiming at the synthesis of useful products. Microbial processes are suitable to use organic nitrogen compounds, such as amino acids, as nitrogen sources for microbes. From his experiments he concluded that fungal hydrolysis of food waste is an appropriate method to recover glucose, protein and phosphate. Food waste hydrolysate is a good breeding material for micro algae; the algal biomass composition was not negatively impacted by the food waste.
https://ini2021.com/the-use-of-nitrogen-compounds-from-organic-waste/

12.3.2 Discussion

The moderator chose several important questions for the panel discussion:

- DASIM: Which process-based models are being compared to the N_2O emissions measured? At what spatial and temporal resolutions do these models simulate N_2O emissions?
- Estimates of global N_2O emissions: You provide denitrification rates on an ecosystem level. Do you think there is high spatial variability within an ecosystem? Would you expect that this denitrification ratio also holds under low-emission farming practices? What about N_2/N_2O emissions that occur after leaching? What are the reasons for the varying N_2O across ecosystem? Will it be possible to reduce the N_2O with some management practices? it is interesting that the comparison you carried out gave a similar value of 8% global N_2O emissions from terrestrial denitrification. When N_2O is measured from the field, the values are notoriously variable due to several factors. What are some potential uncertainties that could be related to the value of 8%?
- Nitrogen compounds from food waste: What are the biggest challenges for the implementation to use food waste as a source for "clean" proteins?

12.4 Session 5b – Biogeochemical N Cycle (N Budget)

Moderator
Barbara Amon

12.4.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

12.4.1.1 Surface Nitrogen Budgets for Cropland and Pastureland on a Global Grid - Opportunities and Challenges (Katrin Kaltenegger)

Katrin Kaltenegger and Wilfried Winiwarter used publicly available sources to map global surface nitrogen budgets on an 0.5-degree grid to indicate areas of N inbalance. Their work is based on a variety of sources like FAO Stat data on harvested yields and crops, IFA data for fertilizer consumption among others.
https://ini2021.com/surface-nitrogen-budgets-for-cropland-and-pastureland-on-a-global-grid/

12.4.1.2 The global nitrogen cycle from 1965 to 2010 (Benjamin Leon Bodirsky)

Benjamin Leon Bodirsky and his co-workers used a new open-source inventory software to estimate N budgets for more than 200 countries for the year 2010. They applied and extended mass-balance methods from the IPCC Guidelines for National Greenhouse Gas Inventories and combined different data sets them with model estimates from the dynamic global vegetation, crop and hydrology model, an aquatic nutrient transport model and atmospheric transport models. The authors identified major uncertainties within the N cycle, i.e. N flows in deep oceans, fixation by natural ecosystems and pastures, fixation by cover and forage crops, emissions from natural ecosystems, N mobilization of wetlands, as well as N_2 and N_2O fluxes from soils.
https://ini2021.com/the-global-nitrogen-cycle-from-1965-to-2010/

12.4.1.3 Are German Forest Soils a Source or Sink for reactive Nitrogen? Model-aided Evaluation of Large-Scale Ground-based Observations (Stefan Fleck)

Stefan Fleck and his colleagues investigated the retention of N compounds in German forests with special attention on fluxes in upper and deeper mineral soils. They found that the forests in general act as N sink. In the top soils, N stock changes could be observed due to retention of N input. In the subsoil, stock changes could not be demonstrated. But recent forest dieback showed a high vulnerability of above and belowground nitrogen storage under conditions of climate change: Nitrogen released from decomposition cannot be assimilated by dead forest stands and will most probably be leached to groundwater aquifers or surface waters.
https://ini2021.com/are-german-forest-soils-a-source-or-sink-for-reactive-nitrogen/

12.4.1.4 Mitigating Reactive Nitrogen Loss and Associated Environmental Damage: Opportunities from Changes in Food Production and Consumption Practices in China (Yixin Guo)

Yixin Guo and her colleagues from the USA, China and the UK analysed a series of agriculture-management and food-demand strategies aiming at lower N_r losses in China. The management measures included reduced fertilizer application, use of more efficient fertilizers, replacement of hand application of fertilizers by machines, and improved manure management. Furthermore, models included different diets, e.g. the present Chinese diet, guidelines for healthy and sustainable diets, and replacement of red meat by soy. Lower NH_3 and N_2O as well as $PM_{2.5}$ emissions can be obtained by a combination of all technical improvements. Greater soybean intake and removal of red meat production decreased the emissions even more also providing co-benefits including improved nutritional health. It was also demonstrated that reduction of N_r losses lead to considerable economic benefits.
https://ini2021.com/mitigating-reactive-nitrogen-loss-and-associated-environmental-damage-opportunities-from-changes-in-food-production/

12.4.1.5 Is Nitrogen the Next Carbon? (Viney P. Aneja)

Viney P. Aneja and his colleagues demonstrated the enormous increase of N_r from various sources. Since 1960, human-induced production of N_r compounds increased by almost a factor of five, while emissions of carbon compounds increased by a factor of about three. About 70% of applied N fertilizers are lost. He highlighted the relation between the natural N cycle and anthropogenic N fixation that is balanced by denitrification. This balance will probably not be continued in case of further increasing emission of N_r, but the impacts are not clear. Further denitrification might also lead to an increase of N_2O concentrations thus accelerating climate change. They concluded that mitigation of nitrogen pollution is an enormous challenge that is comparable to the reduction of greenhouse gases.
https://ini2021.com/is-nitrogen-the-next-carbon/

12.4.2 Discussion

In the lively discussion, the following subjects were mentioned:

- Sources and reliability of the data used for the estimation of the N budgets.
- How to make progress of the N estimates on the 0.5-degree grid model?
- Magnitude of uncertainties in global N flows
- How to cope with “unquantified” flows with respect to administration and policy?
- Effects of forests on nitrate concentrations in groundwater
- Comparison of N_r emissions in East Asia and Europe

13 Theme 6: Closing the N cycle: Innovations for sustainable N management

13.1 Session 6a - Better management of dairy and crop systems

Moderator
Albert Bleeker

13.1.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

13.1.1.1 Balancing nitrogen inputs for China‘s green agricultural development (Liu Xuejun)

Liu Xuejun and colleagues from China, the Netherlands and the United Kingdom assessed an overall N balance for China. They calculated the required N input (for food security) and the critical N input (for avoiding environmental harm) during 1950 and 2015 based on improved planetary boundaries and summarized literature data. The required N input increased from 14 (1950) to 30 Tg N yr^{-1} (2015), respectively. The critical N input was calculated to be 32 Tg N yr^{-1} on average based on nitrate leaching and NH_3 emission thresholds. The actual N input was much lower than the required and critical N inputs in 1950 and close to those inputs in 1980 but substantially higher in 2000 and 2015. The authors proposed a three-step strategy to achieve a balanced input, i.e. use of effectively recycled manure instead of synthetic fertilizer, reduction of N fertilizer inputs based on the crop N demand, and integrated soil-crop system management, including optimized N fertilization techniques and optimized crop management.
https://ini2021.com/balancing-n-inputs-for-chinas-green-agricultural-development/

13.1.1.2 Decoupled aquaponics - Innovative food production systems for a sustainable nitrogen management (Hendrik Monsees)

Hendrik Monsees and his colleagues presented a study on aquaponics that offer an innovative approach to reduce nitrogen emissions and the use of N-fertilizer for the combined production of fish and plants in closed production systems. In this special case, recirculating aquaculture systems for fish production were combined with hydroponics for soilless plant production thereby recycling dissolved nutrients derived from metabolism of the fish. The use of fish water saved 63% mineral fertilizer and fully substituted the required water for the nutrient solution in comparison to the control.
https://ini2021.com/decoupled-aquaponics-innovative-food-production-systems-for-a-sustainable-nitrogen-management/

13.1.1.3 Reducing ammonia volatilization and nitrous oxide emissions from agricultural soils (Craig Drury)

Craig Drury and his co-workers demonstrated how to reduce N losses to NH_3 volatilization and N_2O emissions from urea-based fertilizers and thereby enhance N uptake and crop yields. As the use of urease inhibitors decreases losses by gaseous NH_3 and at the same time enhances production of N_2O, a holistic N application approach is required. Form their field experiments with maize over six years they concluded that both NH_3 volatilization as well and N_2O emissions were reduced when both urease and nitrification inhibitors were used together. https://ini2021.com/reducing-nh3-volatilization-and-n2o-emissions-from-agricultural-soils/

13.1.2 Discussion

This session was dedicated to technical innovations for a better management of crop and dairy systems aiming at less wasted nitrogen. In the discussion, several questions were raised:

- Balancing N inputs for China: How can the gap between the actual N use and the N requirements reduced without influencing the yield? Why have enhanced efficiency fertilizers not been considered as a potential strategy for decreasing N input while decreasing N_r losses? What is the biggest challenge?
- Reducing ammonia volatilization and nitrous oxide emissions: Why does the NH_3 volatilization increase with the use of inhibitors? What are the reasons for the lower yields with inhibitors in one season?

13.2 Session 6a - Technologies and nutrient recovery

Moderator
Cláudia Marques dos Santos Cordovil

13.2.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

13.2.1.1 Ground level and aerial sensors to detect crop N status and adjust fertilizer application (María Dolores Raya-Sereno)

María Dolores Raya-Seleno's talk focused on ground level and aerial hyperspectral sensors to optimise fertilization on the ground. Together with her co-authors, she compared two systems, namely Dualex® and Greenseeker®, in a field study over two years. The results generally confirmed that remote sensing is a useful tool to detect the N status of the crops. However, only ground sensors detected differences in N fertilizer residual effect.
https://ini2021.com/ground-level-and-aerial-sensors-to-detect-crop-n-status-and-adjust-fertilizer-application/

13.2.1.2 Catalytic Conversion of Nitrogen Oxide to Ammonia (Yuichi Manaka)

Yuichi Manaka proposed to use a reducing agent to save energy, i.e. to produce NH_3 from NOx. For that objective they tested catalysts in the form of grains. A combination of Platinum and TiO_2 showed to be effective. The rutile crystalline form was the most effective catalyst yielding ammonia at 200°C.
https://ini2021.com/catalytic-conversion-of-nitrogen-oxide-to-ammonia/

13.2.1.3 Recovery of gaseous ammonia released from livestock farms by recyclable adsorbent (Tohru Kawamoto)

Tohru Kawamoto and co-workers presented an adsorption system for recovery of gaseous NH_3 released from livestock farms and composting facilities. Up to now, a great part of the ammonia produced is lost. The adsorbent is based on a modified Prussian blue pigment that turned out to be very effective and selective to NH_3 also in humid air. This adsorbent is more efficient than commercial products, and needs a short contact time only. After desorption the material can be re-used. NH_3 can be processed as fertilizer. In the discussion, potential carryover of Copper was raised because of impacts on soil.
https://ini2021.com/recovery-of-gaseous-ammonia-released-from-livestock-farms-by-recyclable-adsorbent/

13.2.1.4 Innovative explorations of subsurface redox conditions for future targeted N regulation (Birgitte Hansen)

Birgitte Hansen and co-workers presented how mapping subsurface conditions allows to improve the success of mitigation measures and targeted regulation for N, adjusted to site-specific hydrogeological and geochemical characteristics of the subsurface of the catchment. She highlighted the importance of the hydrogeological layers (extension, chemical characteristic etc.) for enzymatic reactions of N compounds and flow of nitrate. N retention maps are constructed by integrating hydrogeological layers with hydrogeochemical layers. This mapping is being done with screeners that are carried through the soil surface. This allows to monitor physical and chemical soil conditions. The texture, nitrate, and reduction conditions are monitored. In the discussion, the costs of the technique were debated inter alia.
https://ini2021.com/innovative-explorations-of-subsurface-redox-conditions-for-future-targeted-n-regulation/

13.2.1.5 Plasma treatment of dairy slurry increases grass yields and nitrogen use efficiency (Nick Humphries)

Nick Humphries and his co-workers demonstrated the utility of plasma treatment of livestock slurries and biogas digestates by increasing its overall N content and simultaneously reducing the emission of ammonia and methane. This process enriches the substrate with added N in the form of nitrate and lowers the pH, preventing ammonia loss to the atmosphere and thereby increasing NUE. Carbon, Phosphorous, Potassium and Magnesium at the same time are maintained in the treatment. Field studies were performed in different regions. The method will be improved in terms of odour control and farm implementation. Also, in this case, the applicability will depend on the price.
https://ini2021.com/plasma-treatment-of-dairy-slurry-increases-grass-yields-and-nitrogen-use-efficiency/

14 Theme 7: Integrated science and policy approaches – Social and public awareness sessions

14.1 Session 7a – From science to policy (economic issues) I

Moderator
Hans van Grinsven

14.1.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

14.1.1.1 Costs of regulating ammonia emissions from livestock farms near Natura 2000 areas - Analyses of cases (Brian H. Jacobsen)

Brian H. Jacobsen looked to farm scale and implication of abatement requirement (nitrate and ammonia) for farm production cost (per unit of produce) and competitiveness.
https://ini2021.com/costs-of-regulating-ammonia-emissions-from-livestock-farms-near-natura-2000-areas/

14.1.1.2 The social cost of nitrogen - with examples from Germany (Bernd Hansjürgens)

Bernd Hansjürgens focused on the public benefits of reducing N for Germany using the Unit Damage Costs derived in the European Nitrogen Assessment. He pointed out the poor current representation of the current public cost in policy and food prices (in line with the keynote by Friedhelm Taube).
https://ini2021.com/the-social-cost-of-nitrogen-evidence-from-germany/

14.1.1.3 Developing a global economic valuation function for nitrogen impacts on coastal and marine ecosystem services (Rute Pinto)

Rute Pinto developed novel value functions for both abatement costs (per kg N) and public benefits (per person) of reducing N loads for marine basins and using the rich data from the Baltic Basin. She also explored extrapolation to other marine systems and global upscaling.
https://ini2021.com/developing-a-global-economic-valuation-function-for-nitrogen-impacts-on-coastal-and-marine-ecosystem-2/

14.1.2 Notes by the moderator

While all three talks addressed economic aspects of the N cycle they are very different regarding objective, approach and scale.

All speakers stressed both the relevance of economic results for policy but also that we need to be very careful. Brian demonstrated how regulatory systems differ per country and different farm cost structures, so for cross national comparisons the devil is in the detail. Rute pointed out the uncertainties when using value functions based on Baltic to marine systems with other chemistry, hydrology and biology, and to regions with other socio-economics, culture and preferences. She stressed the need for validation of valuation function before applying to other contrasting world regions. The commonly used GDP elasticities for the cost of N pollutions tend to reduce cost of N externalities to very low value in low income countries. An attendee from South Asia remarked that the extent of impacts of N pollution to environment and human health is of concern for public and policy Bernd reported the German experience with regard to Nitrate removal from drinking water: Costs are really high; when extrapolated to total German area the costs amount to multiple billon euro outweighing the farm benefits. For the waterworks, it is cheaper to compensate farmers for low-nitrate or no-nitrate agricultural practices than to apply ex-post treatment to meet the Nitrate standards.

Access to clean air and water is a global fundamental right. One of the most robust outcomes of environmental economic analysis over the past 10 years is that the public cost (disease and premature mortality) of nitrate pollution of drinking water is at least one order of magnitude lower than of N_r pollution of ambient air. Still nitrate in drinking water remains an equally high public concern in Germany and Denmark, and in parts of South Asia is given higher priority – how should we deal with that? The preferred measures against hazards by N_r apparently do not cover all relevant problems, e.g. acute effects of polluted drinking water (diarrhoea, (rare) blue baby disease) vs. delayed impacts of air pollution.

Summing up the session, the moderator underlined the need for guidelines for proper use of external costing in policy advice. For example, clear rules for internalizing external cost of N pollution in farm gate or consumer prices. Other countries should avoid the mistakes known from Europe and North America and skip the phase of fast economic growths and extreme pollution.

14.2 Session 7a – From science to policy (economic issues) II

Moderator
Johannes Biala

14.2.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

14.2.1.1 Trends in nitrogen induced costs due to impacts on human health, climate and ecosystems in Europe (Wim de Vries)

Wim de Vries and his co-authors presented a review illustrating the inputs of reactive nitrogen (NO_x, NH_3, N_2O and N runoff) and various impacts on human health, climate and terrestrial and aquatic ecosystems in Europe from 1990 until 2015. The cost benefit analysis showed that environmental costs of reactive N release to the environment decreased because of European restrictions, but exceeded the direct economic benefits for agriculture even in the period from 2010 to 2015.
https://ini2021.com/developing-a-global-economic-valuation-function-for-nitrogen-impacts-on-coastal-and-marine-ecosystem/

14.2.1.2 A reflexive policy approach for designing a Farm-Gate Nitrogen Surplus Tax (Luisa Stuhr)

Luisa Stuhr mentioned the often diverging perspectives and realities of farmers, consumers and policy decision makers. Together with Benjamin Bodirsky, she proposed a tax on surplus N to be paid by the farmers. The design of the tax should be used as a model for reflexivity in agricultural policy.
https://ini2021.com/a-reflexive-policy-approach-for-designing-a-farmgate-nitrogen-surplus-tax/

14.2.1.3 Societal benefits of halving agricultural ammonia emissions in China far exceed the abatement cost (Xiuming Zhang)

Xiumin Zhang pointed out that there are considerable societal benefits for China to reduce agricultural NH_3 emissions compared to its implementation costs. The technical mitigation potential of agricultural NH_3 emissions in China is about 50%. Saving unnecessary N fertilizer use and protein-rich feed could provide 30% of mitigation potential without abatement costs. This contribution China demonstrated the enormous economic opportunities related to optimisation of nitrogen use efficiency:
https://ini2021.com/societal-benefits-of-halving-agricultural-ammonia-emissions-in-china-far-exceed-the-abatement-cost/

14.2.1.4 Cost-effective nitrogen load reductions to Danish coastal areas – comparison of three economic models (Berit Hasler)

Berit Hasler and her co-workers presented some economic models to support decision makers in their choices for effective nitrogen load reductions from a number of catchments in Danish coastal areas.
https://ini2021.com/cost-effective-nitrogen-load-reductions-to-danish-coastal-areas/

14.2.1.5 Willingness to pay for improvements in surface water quality in Northern Europe: A meta-regression (S. B. Olsen)

S. B. Olsen et al. performed a meta-study based on 34 primary publications aiming at a regression function between costs and impacts of water quality in Scandinavia. The results will improving the validity and reliability of benefit transfer in relation to costs.
https://ini2021.com/willingness-to-pay-for-improvements-in-surface-water-quality-in-northern-europe/

14.2.1.6 Cost-benefit analysis of reactive nitrogen for Germany (Bettina Schäppi)

Bettina Schäppi and her co-authors quantified costs and benefits related to nitrogen input to the environment for Germany across all sectors for 2015 and 2030. They demonstrated that the economic benefit of primary agricultural production attributed to application of reactive nitrogen is lower than the sum of direct costs of fertilizer application and social cost due to environmental degradation, both in 2015 and in 2030. In case of enhanced mitigation action, the scenario for 2030 results in a net benefit.
https://ini2021.com/cost-benefit-analysis-of-reactive-nitrogen-for-germany/

14.2.1 Notes by the moderator

In Northern Europe, action against surplus N is already in place since many years. The experience collected there allows to find appropriate ways of reducing N pollution. The moderator noted that it is interesting to learn about the progress various countries had already made in reducing excess N use in agriculture and associated negative environmental impacts through a wide range of policy measures that include carrot and stick approaches.

The moderator underlined that 'there is still a long way to go to meet EU targets' despite considerable progress already made in Europe. He particularly mentioned the face of resistance among farmers to more regulations and restrictions. Although there are now models that can predict 'willingness to pay', market mechanisms on their own will not be adequate to bring the desired change - this can be only achieved if there is strong regulatory support for measures to reduce N pollution. It became clear that efforts to reduce N pollution have to be supported and funded by society as a whole, rather than be targeted only at farmers.

The discussion focused on the question as to whether and to what degree N pollution can be reduced through non-regulatory, market-based measures, or whether regulations are inevitable in order to make progress. The presentations and ensuing discussion clearly said that, from a European perspective, it is impossible to make significant headway without (i) strong regulations, (ii) broad societal support, (iii) support and compensation payments, and (iv) robust science (incl. social science) to support political decisions.

The facilitator pointed out that the long and varied history of successes and failures of European countries in curbing N pollution should be studied by other countries that start tackling this problem only now even if the frame of European policy cannot be copied. He proposed the publication of a 'brief history of reducing N pollution in Europe', focusing on successes and failures of various policy and other measures that should be edited by some colleagues from Europe who are particularly working in this field.

14.3 Session 7b - Educational aspects, public awareness, risk communication (communication I)

Moderator
Wim de Vries

14.3.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

14.3.1.1 A revised planetary boundary for agricultural nitrogen use (Lena F. Schulte-Uebbing)

Lena F. Schulte-Uebbing and her colleagues calculated the acceptable agricultural N input on a global scale, considering the uneven distribution of agricultural nitrogen inputs, losses, and related impacts that have not been included in former calculations. They concluded that the safe boundary is about 40% lower than the current inputs and requires geographic reallocation of the N input.
https://ini2021.com/a-revised-planetary-boundary-for-agricultural-nitrogen-inputs/

14.3.1.2 Linking Nitrogen Forms, Quantifications, and Epistemologies: A Science-Policy Interface Issue (William San Martin)

William San Martin stressed the necessity of qualified quantifications of nitrogen forms and effects often leading to uneven trade-offs. He underlined the necessity of a science policy interface in international nitrogen management and governance.
https://ini2021.com/linking-nitrogen-forms-quantifications-and-epistemologies-a-science-policy-interface-issue/

14.3.1.3 National nitrogen budgets of Japan in 2000s (Kentaro Hayashi)

Kentaro Hayashi and co-workers presented a holistic N model for Japan. According to their research, the reduction of N losses to the environment in Japan should focus on NO_x emissions in first priority and much less to ammonia.
https://ini2021.com/national-nitrogen-budgets-of-japan-in-2000s/

14.3.1.4 Governing Nutrient Pollution Beyond Farmers (David Kanter)

David Kanter reported the outcome of a workshop focusing on “Governing Nutrient Pollution Beyond Farmers”. He focused on the science policy interface that should provide selected private and public regulation strategies for N and a framework to support policymakers in their regulatory work. In the discussion, William and David highlighted the need for a broad perspective covering all actors in the food chain, waste management and industry.
https://ini2021.com/governing-nutrient-pollution-beyond-farmers/

14.3.1.5 A guidance document for nitrogen impact assessment for human health and environment qualities (Hideaki Shibata)

Hideaki Shibata and co-workers from research groups in Japan and the U.S. presented a guidance document for policymakers that provides negative and positive impacts of N_r at different spatial scales and their impacts across multiple sectors, contexts and scales. The authors proposed 37 key indicators based on nitrogen related dose-response relationships. The presenter suggested to take a closer look on tropical regions.

https://ini2021.com/a-guidance-document-for-nitrogen-impact-assessment-for-human-health-and-environment-qualities/

14.3.2 Discussion

The moderator summed up the presentations and the discussion:

1. Several N impacts cannot be represented by straightforward N dose-response relationships, since other variables affect the impacts, such as P in surface water eutrophication or VOC in ozone formation.
2. The reduction in N losses to the environment to acceptable levels is in several intensive industrial or agricultural regions not possible with technology alone but also requires a reduction in production (e.g. livestock levels).
3. There is a need for assessing not only global scale acceptable agricultural N inputs, but also N surpluses and N losses to air and water.
4. Governing the activities affecting N emissions from agriculture requires a food chain approach, being much broader than farmers alone but including e.g. producers of fertilizer and retailers.

14.4 Session 7b - Educational aspects, public awareness, risk communication (communication II)

Moderator
Andreas Prüeß

14.4.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

14.4.1.1 A scheme to relate nitrogen loads to characteristic plant species of FFH habitat types in Germany (Sonja Winter)

Sonja Winter presented potential change of plant species composition induced by high nitrogen loads. She developed a scheme that is specific for a particular German FFH habitat (together with Markus Röhl) and defined three trophic levels (10-12, 12-15, >15 kg N $ha^{-1}yr^{-1}$) according to N loads found in literature.
https://ini2021.com/a-scheme-to-relate-nitrogen-loads-to-characteristic-plant-species-of-ffh-habitat-types-in-germany/

14.4.1.2 Integrated evaluation of changes in agriculture in view of climate, biodiversity and water goals (Hans Kros)

Hans Kros and co-workers evaluated the effects of mitigation measures, e.g. changes in feed composition, manure application, crop management etc., to minimize nutrient leaching and runoff, damage for biodiversity and emission of GHGs. The evaluation was performed by using an integrated crop, soil and nutrient management model ("INITIATOR").
https://ini2021.com/integrated-evaluation-of-changes-in-agriculture-in-view-of-climate-biodiversity-and-water-goals/

14.4.1.3 Nitrogen balances in urban areas: purpose and potentials (Wilfried Winiwarter)

Wilfried Winiwarter and co-workers studied the influence of urban environments on the nitrogen cycle using a mass balance approach. Besides higher emission of NOx (traffic etc.) or large N loads wastewater peri-urban agriculture turned out to be particularly wasteful in its use of nitrogen as nutrient.
https://ini2021.com/nitrogen-balances-in-urban-areas-purpose-and-potentials/

14.4.1.4 Nitrogen shares in global environmental impacts and crop production (Hans JM van Grinsven)

A group of international experts studied the effects of extended use of N fertilizer and emissions of reactive N compounds on human health and environment for the different world regions. Hans JM van Grinsven presented the N related impacts (shares) on premature deaths, loss of terrestrial biodiversity, and climate warming. They also calculated the long-term need of synthetic N fertilizer for main crops in the world regions.
https://ini2021.com/nitrogen-shares-in-global-environmental-impacts-and-crop-production/

14.4.2 Discussion

The moderator mentioned the N models used by the presenters Hans Kros and Hans JM van Grinsven and asked for their performance with respect to zoning agriculture emissions. He stated that the nitrogen saturation of the vegetation starts with an ammonia emission of 5 kg N ha^{-1} yr^{-1} respectively concentration of 1 µg NH_3 m^{-3} which is very important for protecting FFH habitat types in (lower) mountain regions in Europe with sensitive vegetation.

According to Sonja Winter, trophic level of FFH habitat types can be an important tool for limiting ammonia and nitrogen emissions. Parameters of the habitat such as biomass, grass/forb-ratio etc. should be partially used for the trophic-schemes as well. Further data on the relationship between NH_3-concentration, N deposition etc. and these parameters will be useful.

The term "N share" used in the talk by Hans van Grinsven was discussed regarding other contributions besides from N_r that also influence impacts on man and environment: Singling out any of these (by model perturbations) can lead to a sum of more than 100%, e.g. contributions of N and S compounds to the formation of aerosols and their effect on mortality. Should interactions, e.g. between NH_3 and SO_2, be considered? Hans JM van Grinsven answered that in this case reaction of NH_3 and SO_2 will lead to the formation of $(NH_4)_2SO_4$ type aerosols. This will indeed lead to an overestimation of "N share", i.e. shares add up to >100%.

Answering questions from the auditory, Wilfried Winiwarter mentioned that further research will focus on the establishment of these concepts derived for test cities to make use of cities' abilities to act more swiftly than countries or even larger units, to support goals like "halving nitrogen waste" and developing towards a "circular economy" of nutrients

According to Hans Kros, results from the model calculations used in their work show that the climate goal is the most restrictive one, because it requires a transition in agricultural practice and a reduction in livestock numbers. Targets for NH_3 emissions and N runoff and leaching will be reached if the climate goals are met.

Summing up the results of the session, Andreas Prüeß remarked that international and national models seem to underestimate the loss of terrestrial biodiversity because the critical ammonia concentration (yearly average) for sensitive species (such as lichens, bryophytes and insects) and habitats are not taken into account accurately.

14.5 Session 7b – Educational aspects, public awareness, risk communication (policy I)

Moderator
Mahesh Pradhan

14.5.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

14.5.1.1 A national nitrogen target for Germany (Markus Geupel)

Markus Geupel and his colleagues from several German Agencies presented national maximum permissible nitrogen releases calculated for six environmental sectors, i.e. vegetation (affected by NH_3-concentration), terrestrial ecosystems (affected by eutrophication), surface waters (to prevent coastal waters from eutrophication), groundwater, climate, and human health. The most sensitive (lowest) release rates per nitrogen species were selected to derive the national nitrogen target of about 1,000 Gg N yr^{-1} by adding them up. The current release rates for 2015 amount to about 1,574 Gg N yr^{-1}.
https://ini2021.com/a-national-nitrogen-target-for-germany/

14.5.1.2 Comparison of regulatory approaches for determining application limits for mineral nitrogen fertilizer use in Germany (Philipp Löw)

Philip Löw and Bernhard Osterburg investigated the impact of three agricultural regulatory approaches based on field-balances, farm-gate balances or fertilizing plans currently applied in Germany on the maximum permitted input rates of mineral nitrogen fertilizer. Using data of about 10,000 farms representing the agricultural sector in Germany, model farms were generated for a comparative study. Results show that the maximum input of mineral nitrogen fertilizer varies approach-specifically at farm level and that the differences greatly depend on the farm-type. Philip concluded that the reliability of farm balance is higher than that of soil balance, whereas fertilization plans are least reliable. The results are of great importance for further regulations to decrease surplus N emissions.
https://ini2021.com/comparison-of-regulatory-approaches-for-determining-application-limits-for-mineral-nitrogen-fertilizer-use/

14.5.1.3 Evaluation and comparison of nitrogen mitigation measures across sectors (Bettina Schäppi)

Bettina Schäppi and her colleagues developed a tool with a compilation of nitrogen mitigation measures from different sectors – industry, transportation, agriculture, households and waste – that have an emission reduction potential. The tool allows sorting and filtering the measures according to different criteria, depending on the interest of the user. Five main criteria were used to evaluate the measures: effectiveness, efficiency, acceptance, technical and legal feasibility. From the excel tool, a profile for each individual measure can be generated. The five main criteria are also displayed in a radar diagram for each measure, which also allows for direct comparisons between measures. The tool allows a holistic and integrative approach that accounts for the complexity of the nitrogen problem.
https://ini2021.com/evaluation-and-comparison-of-nitrogen-mitigation-measures-across-sectors/

14.5.1.4 How the Dutch nitrogen policy failed and led to serious nitrogen deposition reduction (Jan Willem Erisman)

Jan Willem Erisman analysed the development of Dutch policy for the reduction of nitrogen depositions. The so-called Programmatic Approach on Nitrogen (PAS) aimed to reduce nitrogen deposition to the sensitive Natura 2000 areas without affecting economic growth. But this plan was rejected by the highest national court as it would be not sufficient to protect these areas according to European guidelines. As a consequence, no new projects that emit nitrogen oxides or ammonia, are allowed. Therefore, the whole economy is affected: new housing, building roads, an airport, industry, traffic and farmers. All stakeholders must work together to come to sustainable solutions. He discussed some experiences from the “Dutch nitrogen crisis” that are of common interest.
https://ini2021.com/how-the-dutch-nitrogen-policy-failed-and-led-to-serious-nitrogen-deposition-reduction/

14.5.1.5 The Dutch story of an Integrated Approach to Nitrogen, all things come and go (Mark Wilmot)

Marc Wilmot and Wim van der Maas supplemented the talk by Jan Willem. They explained the tools within the Programmatic Approach on Nitrogen and further steps that has been introduced since the decision of the court, e.g. a new threshold limit, below which permitting procedures are not necessary. Further measures can include a reduction of the speed limit on the motorways, reduction of livestock, buy-out of pig farms. A new law for nitrogen reduction including targets for 2025, 2030, and 2035 has already passed the parliament. They introduce a tool (“AERIUS”) that links regulation, monitoring, and evaluation of policy (see also presentation by R.W. Kruit, 7b – Educational aspects, public awareness, risk communication (policy) II).
https://ini2021.com/the-dutch-story-of-an-integrated-approach-to-nitrogen-circular-policy/

14.5.1.6 The political ecology of manure export in Lower Saxony: an ethnographic case study (Friederike Gesing)

Friederike Gesing analyzed the situation of Lower Saxonia, a German State characterized by highly intensive animal farming. In order to maintain stock levels under tighter German fertilizer regulations, manure transports into other regions are a usual measure to meet the regulatory limits. She investigated manure transport and processing as a sociomaterial practice, involving a complex set of actors including slurry banks and logistics companies.
https://ini2021.com/the-political-ecology-of-manure-export-in-lower-saxony-an-ethnographic-case-study/

14.5.1.7 Towards a Credit System to Solve Agriculture induced Nitrogen Pollution Globally (Deli Chen)

Deli Chen and a number of colleagues presented a generic N credit system (NCS) that was inspired by existing carbon credit systems. The NCS shall incentivize the reduction of agricultural pollution and improve shared responsibilities among farmers, suppliers, processors, retailers, consumers and governments. The feasibility and priorities for the NCS depend strongly on the development stage of the implementing country regarding food security, education, economy, access to technology and presence of institutions. Therefore, a tiered approach to build NCSs appropriate to different stages of development and relevant natural resources was proposed.
https://ini2021.com/credit-system-to-solve-agricultural-nitrogen-pollution-globally/

14.5.2 Discussion

These contributions were followed by a lively discussion. The audience and the moderator posed the following questions for discussion:

14.5.2.1 National German N target

What kind of activities are planned for communication of the new N target by the Ministry for Environment?

14.5.2.2 Dutch N crisis

How was the goal aiming at the reduction of N deposition defined? How was the goal derived, i.e. why 75 % of the sensitive ecosystems should meet Critical Loads? It was said that 70 % percent emission reduction is necessary to meet the Critical Loads in 96 % of the sensitive ecosystems - which contributions have to be reached by the different sectors? Which assumptions did you make for emission reductions in neighbouring countries? Why did nature protection and Critical Loads exceedance became so important in the Netherlands that such drastic measures were taken? Why is policy less strict and debate is less boiling in countries, that face similar problems? Has nitrogen become equally important than climate change in the Dutch political debate or is it even more important? Did the Nitrogen crisis also facilitate public understanding of N as an integrated issue? The Netherlands is considering some new approaches to restoration that focus on removing nutrients such as removing soil, cutting sod or grass - is there a research effort to determine if these approaches are likely to work, at multiple scales? Is the use of the AERIUS tool in Germany already on its way?

14.5.2.3 N credit system:

Does this mean that the price for one tomato sold in Australia would be put together by different factors, such as the country where it comes from and the form how it was produced? This would mean, that a huge database for all kind of products would be necessary. Are there already countries that implemented an environmental index for agricultural products? How shall the effect on consumers' behaviour be estimated?

14.6 Session 7b – Educational aspects, public awareness, risk communication (policy II)

Moderator
Borhane Mahjoub

14.6.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

14.6.1.1 How Danish farmers have doubled N efficiency already & how to reach ambitious future targets (Wibke Christel)

Wibke Christel and her colleagues demonstrated how nitrogen losses to atmosphere and aquatic environment could be considerably reduced in Denmark, while farmers - despite the costs – managed to increase productivity. This can mainly be assigned to a significant increase in NUE in both livestock and arable farming. Long term monitoring data shows that water and air quality have increased. However, environmental pollution still remains a concern and requires more nutrient-loss-reductions. For improved cost-efficiency, further mitigation measures should be targeted to specific water bodies or habitats. She also mentioned new challenges, e.g. the adaptation to climate change or changes in agricultural practices.
https://ini2021.com/how-danish-farmers-have-doubled-n-efficiency-already-how-to-reach-ambitious-future-targets/

14.6.1.2 How Germany's national air pollution control programme contributes to reduced emissions of reactive nitrogen into the atmosphere (Marcel Langner)

Marcel Langner and his colleagues presented the successful implementation of European standards for air pollutants into German law. Germany had to reduce the national emissions of pollutants contributing to reactive nitrogen in the atmosphere, i. e. NO_x and NH_3, in a first step by 39 % and 5 % until 2020 compared with 2005 for NO_x and NH_3, respectively. These targets were reached in 2020. In a second step emission reductions by 65 % for NO_x and 29% for NH_3 until 2030 shall be achieved. Additional measures covering agriculture, medium-sized combustion facilities and the transport sector, already partly adopted, will be necessary to meet these targets.
https://ini2021.com/how-germanys-national-air-pollution-control-programme-contributes-to-reduced-emissions-of-reactive-nitrogen-into-the-atmosphere/

14.6.1.3 Natura 2000 as a strategic element of Nitrogen reduction policy (Rudolf Uhl)

Rudolf Uhl highlighted the European Natura 2000 network to protect natural habitats and wild species as a strategic instrument to reduce nitrogen emissions. (See also the contributions by Jan Willem Erisman and Mark Wilmot in the session 7b Educational aspects, public awareness, risk communication (policy I)). Protection is governed by the EU habitats directive, which provides instruments to survey, monitor, maintain and develop specific structures and functions of natural habitats and the natural range and population of species. In order to fulfil requirements for appropriate assessments of roads, an assessment method was developed based on the concept of critical loads that can be transferred to other sectors. He recommended to use appropriate assessments in the permission procedures, to prohibit, mitigate or compensate

negative impacts of projects on nature that often include nitrogen reduction targets.
https://ini2021.com/natura-2000-as-a-strategic-element-of-nitrogen-reduction-policy/

14.6.1.4 Nitrogen balance and water contamination risk assessment - The Castelo de Bode watershed example (Maria Vale)

Maria Vale and her colleagues presented an innovative approach to risk evaluation and prevention to water stress caused by N related pollutants. The Castelo de Bode watershed (Portugal) was used as an example to demonstrate the relevance of collaborative web based data management platforms for the assessment of N contamination risk. A broad approach was taken integrating, development concerns and water resources allocation. She underlined the opportunities by integrating scientific findings on N related water problems, planning, management and allocation of resources, and monitoring to come to cost-effective solutions on a local level.
https://ini2021.com/nitrogen-balance-and-water-contamination-risk-assessement/

14.6.1.5 The Dutch integrated approach to monitor and calculate nitrogen deposition in Natura 2000 areas (Roy Wichink Kruit)

Roy Wichink Kruit presented the monitoring tool AERIUS. The tool was developed for determining the level of nitrogen deposition in Natura 2000 areas and the contribution of new projects and development plans. In this way, the system combines two important functions: monitoring the nitrogen deposition and calculating impacts of individual projects on Natura 2000 areas. Thus, measures can be targeted on a local level (see also the contribution by Mark Wilmot in the session 7b Educational aspects, public awareness, risk communication (policy I)).
https://ini2021.com/the-dutch-integrated-approach-to-monitor-and-calculate-nitrogen-deposition-in-natura-2000-areas/

14.6.1.6 The first global nitrogen policy database (David Kanter)

David Kanter and his co-workers set up the first global database of national and regional nitrogen policies. The following sources are used: ECOLEX, the largest available database of environmental laws, with over 150,000 local, national and regional laws in addition to international treaties. It combines the law holdings of the FAO, the IUCN, and the UNEP. He presented some results of an analysis of these regulations, e.g. sink or sector approaches, target compounds. He highlighted that most regulations have been issued by OECD countries. David underpinned that there are very few policies that take an integrated approach to N pollution.
https://ini2021.com/the-first-global-nitrogen-policy-database/

14.6.2 Discussion

These contributions were followed by a lively discussion. The audience and the moderator posed the following questions for discussion:

14.6.2.1 Germany's air pollution control programme

Is there a risk that measures to reduce NH_3 will take more time to be implemented? With very limited reductions the last 10 years what will make the change towards 2030? Do measures also target existing buildings?

14.6.2.2 Nitrogen balance and water quality

Has the data quality of the results been analysed so that users can understand their reliability for future work? How does Germany manage the N impacts in these areas among property owners?

14.6.2.3 N policy database

How many policies are using a regulatory approach, and how many a soft approach more based on information etc.?

14.6.2.4 AERIUS model

How often new projects actually will not be realized when the AERIUS tool results in too high extra loads to habitats? Was this tool also used when the "old" room for development was used locally? Is it a surprise that there was room anywhere?

15 Theme 8: Special sessions and closing session

15.1 Special Session on Forests

Moderators
Ann-Katrin Prescher and Kai Schwärzel

15.1.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

15.1.1.1 Continental-scale forest growth in Europe is driven by management and further modulated by nitrogen deposition (Sophia Etzold)

Sophia Etzold and her colleagues from numerous European research institutions analysed continental-scale forest growth data obtained over the period 1995-2010 from nearly 100,000 trees distributed in 442 even-aged, almost pure beech-, oak-, spruce- and pine-dominated forests. They found that, despite the large environmental gradients encompassed by the forests examined, stand density and age were key drivers of forest growth. Moreover, positive, in some cases non-linear effects of N deposition were detected with a tipping point at ca. 30 kg N ha^{-1} yr^{-1}. N deposition was involved in interactions with site quality indicators and had indirect negative effects by altering soil pH and foliar nutrient concentrations.
https://ini2021.com/continental-scale-forest-growth-in-europe-is-driven-by-management-and-further-modulated-by-nitrogen-deposition/

15.1.1.2 Nitrogen impacts on forest mycorrhizas and functions (Martin Bidartondo)

Martin Bidartondo presented relationships between N deposition and mycorrhizal shifts across scales. At large-scales, there are major changes in dominant trees and dominant fungi, and strong declines in key mycorrhizal fungi of pine, spruce, beech and oak. Critical loads should be adjusted down to 5-6 kg N ha^{-1} yr^{-1}. So far, there is only limited and indirect evidence of recovery, particularly across tipping points. Mycorrhizal functional changes include marked decreases in the abundance of mycorrhizas with medium-distance soil exploration capacity and the ability to scavenge for soil organic N that may lead to change in soil organic matter decomposition rates under N pollution. The effect of emerging P-limitation driven by N deposition on forest mycorrhizas is yet poorly understood, but relationships between mycorrhizal structures and foliar N/P ratios have been found.
https://ini2021.com/nitrogen-impacts-on-forest-mycorrhizas-and-functions/

15.1.1.3 Tree nutrition increasingly imbalanced in European forests (Inken Krüger)

Inken Krüger and her colleagues from Germany, Croatia and Finland investigated foliar element concentration ratios at 469 forest sites to detect imbalances in tree mineral nutrition. Those occur when the relative availability of nutrients changes, today mainly due to high N availability. They found that nutrient imbalances are more frequent in broadleaf than in coniferous forests. Overall, both foliar P and N concentrations decreased significantly over the past two decades. The rate of decrease in foliar P is more than twice as high as in foliar N, resulting in a shift towards higher N/P ratios. Detected nutrient imbalances have the potential to limit tree growth, affect tree vitality, and impact the response of forest ecosystems to global change.
https://ini2021.com/tree-nutrition-increasingly-imbalanced-in-european-forests/

15.1.1.4 Nitrogen deposition and leaching in European forests (Elena Vanguelova)

Elena Vanguelova presented results from continuous monitoring of European forests. Though the N deposition has decreased in the last decade in comparison to former years, Critical Loads of nitrogen are exceeded at many forest sites particularly in Central Europe. Leaching of nitrate also decreased. The relationship between N deposition and leaching of nitrate is not simply linear. As with N deposition, N leaching is influenced by forest type, age and soil type amongst other factors and will also widely depends on the amount and fate of nitrogen deposition. Trends of N leaching are region and scale specific.
https://ini2021.com/nitrogen-deposition-and-leaching-in-european-forests/

15.2 Special Session on Nitrogen Footprints

Moderators:
James N. Galloway, Allison Leach

15.2.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

15.2.1.1 Input-output analysis of reactive nitrogen flows in industry and industrial nitrogen footprint: the case of Japan (Kiwamu Katagiri)

Kiwamu Katagiri and his colleagues developed a new model of intercations between different industrial sectors based on input-output analysis to investigate the direct and indirect N_r flows in Japanese industry. The model revealed that the final chemical production sector received the biggest amount of N_r as feedstock among sectors in 2011 (intermediate compounds: Urea, nitric acid, and others). The demand for N_r, particularly Acrylonitrile and Caprolactam, is mainly caused by the production of synthetic fibres, synthetic resins and textile products. Applying the model, the Japanese N footprint of industrial products was found to be 770 Gg-N.
https://ini2021.com/nput-output-analysis-of-reactive-nitrogen-flows-in-industry-and-industrial-nitrogen-footprint/

15.2.1.2 Nitrogen-neutrality Fosters More Sustainable Meetings (Xia Liang)

Xia Liang and her colleagues presented the experiences and status of "Nitrogen neutrality conferences". N-neutrality has been proposed and applied when organizing research meetings to reduce N_r losses from the related activities (e.g. flight, transport, food supply and energy use) and offset the rest N_r losses elsewhere (e.g. afforestation programs, food waste reduction projects). N-neutrality provides an opportunity for more sustainable meetings and can be further incorporated with other environmental measures to improve overall sustainability of events. She discussed the strengths and weaknesses of in-person, virtual, and hybrid conferences from environmental and socioeconomic perspectives.
https://ini2021.com/nitrogen-neutrality-fosters-more-sustainable-meetings/

15.2.1.3 The nitrogen footprint of Denmark - Applying Danish virtual nitrogen factors to estimate losses from food production (Morten Graversgaard)

Morten Graversgaard and his colleagues developed virtual nitrogen factors (VNF) for plant products, fruits and crops aiming at the calculation of N footprints for different sectors. He presented preliminary figures on food consumption, food production, transport, housing and goods and services. The highest share comes from food production (27.2 kg N cap^{-1} yr^{-1}) followed by food consumption (2.6 kg N cap^{-1} yr^{-1}).
https://ini2021.com/the-nitrogen-footprint-of-denmark-applying-danish-virtual-nitrogen-factors-to-estimate-losses-from-food-production/

15.2.1.4 Towards a practical environmental footprint tool (Allison Leach)

Allison Leach (together with colleagues) presented the status of the environmental footprint tool covering footprints of C, N, P and water. Besides the integration of footprints (available as app), footprint categories driven by consumer behaviour were identified and costs for damage by C and N calculated. She demonstrated the applicability of the environmental footprint tool by means of an example, i.e. a university campus. The information provided by the tool will help campuses tackle the portion of their footprint that is due to consumer behaviour through targeted management strategies.
https://ini2021.com/how-germanys-national-air-pollution-control-programme-contributes-to-reduced-emissions-of-reactive-nitrogen-into-the-atmosphere-2/

15.2.1.5 Trends in the food nitrogen and phosphorus footprints for China, India, and Japan (Azusa Oita)

Azusa Oita and her co-workers studied the development of N and P footprints. They developed a common framework to allow a comparative evaluation of nutrient footprints and applied it to the N and P footprints for China, India, and Japan from 1961 to 2013. The footprints increased remarkably in China after 1976. In India, the footprints gradually increased since 1976. In Japan, the footprints greatly increased until 1993 before slightly declining. The key items differed for each country and changed over time, reflecting changes in the N and P use efficiency, dietary changes and differences in food cultures. The reduction of nutrient footprints can be achieved by consumption of low-footprint food and efficient production – both strategies are of importance.
https://ini2021.com/trends-in-the-food-nitrogen-and-phosphorus-footprints-for-china-india-and-japan/

15.2.1.6 Environmental footprint family to address local to planetary sustainability and deliver on the SDGs (Davy Vanham)

Davy Vanham presented proposals of an international working group (23 experts from 17 institutions) aiming at a consistent footprint family that can be used for the assessment of environmental sustainability. The group analysed their relations to the nine planetary boundaries and visualized the crucial information they provide for local and planetary sustainability. The working group also assessed how the footprint family delivers on measuring progress towards Sustainable Development Goals (SDGs) and related them to the water-energy-food-ecosystem (WEFE) nexus. Davy pointed out that the footprint family is a flexible framework where particular members can be included or excluded according to the context or area of concern.
https://ini2021.com/environmental-footprint-family-to-address-local-to-planetary-sustainability-and-deliver-on-the-sdgs/

15.2.1.7 Expanding the Nitrogen Footprint Pathway (James N. Galloway)

James N. Galloway and his co-workers provided a brief history of Nitrogen Footprint calculation, the status of current projects and future plans for the use of footprint tools to minimize the impacts of resource used by people, communities and institutions. He pointed out that N Footprint tools for countries, institutions, rural and urban areas, watersheds etc. are widely used. Some tools have been expanded to C, P and/or water depending on the use.
https://ini2021.com/expanding-the-nitrogen-footprint-pathway/

15.2.1.8 Indian food nitrogen footprint towards 2050: Religious dietary perspective (Aurup Ratan Dhar)

Aurup Ratan Dhar and his colleagues estimated the food N footprint in India considering religious dietary variations during 1961–2013 to forecast the footprint for 2050. The food N footprint in India increased by 19%, where vegetarian Buddhist diet consistently had the lowest contribution. He predicted a 3.9% decrease in India's food N footprint by 2050. As religious dietary regulations strongly affect the food choices of individuals and the resulting N footprints, the promotion of diet awareness among religious groups for improved N management and lowered N footprint of food was recommended. Particularly, diets preferred by Buddhists can help to lower the N footprint.
https://ini2021.com/indian-food-nitrogen-footprint-towards-2050-religious-dietary-perspective/

15.2.1.9 The N-Footprint of the agricultural research station at Aarhus University in Denmark utilizing an N-Institution calculator (Morten Graversgaard)

Morten Graversgaard presented the N Footprint of the Research Center Foulum (Aarhus University, Denmark) which was performed by an international group of researchers. The N-Footprint integrating six different sectors was calculated at 306 kg N yr^{-1}. They concluded that even when using the same set of calculation methods, no one institution is similar. This leads to the need to use more on-site-specific production parameters and to use a more versatile method of calculating the N contribution from all sectors.

In the discussion, Davy Vanham was asked, how pressure indicators can be related to impact indicators, e.g. N footprint to biodiversity footprint. Davy pointed out that models exist that relate pressures to impact. He mentioned the LCA community: Several of such models link pressure and impact, e.g. on eutrophication and acidification (most relevant for N). The biodiversity footprint is very complicated and least developed.

An important question was raised to Jim Galloway when he was asked for his opinion on footprint targets and how to define: Should it be a personal, regional, national or global target? The discussion could not be finalized, however, it was stated that for user friendliness and applicability and comparability target values are needed.
https://ini2021.com/the-n-footprint-of-the-agricultural-research-station-at-aarhus-university-in-denmark-utilizing-an-n-institution-calculator/

15.3 Special Session Nitrogen Use Efficiency and Sustainable Nutrient Management – Crops

Moderators:
Luis Lassaletta, Xin Zhang

15.3.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

15.3.1.1 Changed crop type and crop rotation as a measure to increase N use efficiency and achieve reduction targets for N leaching (Tommy Dalgaard)

Tommy Dalgaard and his colleagues investigated changes in NUE and nitrogen leaching as a function of cropping systems aiming at an optimisation of crop types and crop rotations. The research group used data from digital registers of field crops that are mandatory in the EU. Based on these data, and a coupling to digital field maps and information on fertiliser use, catch crops etc., a database on crop types and crop rotations was set up, and combined with digital maps of N leaching reduction targets for Danish watersheds. The model also simulates N losses depending on soil type, geology, precipitation etc. The authors concluded that the selection of appropriate crops, e.g. more grass and green refineries, and adjusted crop rotation offers a significant potential to combine reduced pollution with higher NUE and possible economic benefits.
https://ini2021.com/changed-crop-type-and-crop-rotation-as-a-measure-to-increase-n-use-efficiency/

15.3.1.2 Coffee plants have low NUE (Felipe Santinato)

Felipe Santinato and his co-workers presented NUE data for Brazilian coffee plants (468 sites/years over 20 years). According to their research, only 15 to 17% of the N fertilizer are exported with beans and 27 to 30% when beans and husks are accounted. The average N surplus of these fields varied from 293 to 300 kg N ha^{-1} (when beans and husk were removed from the field). As farmers are usually reluctant to reduce N fertilization because of the high yield responses, strong effort is needed to find ways to increase NUE for coffee plants, preserving yields, and effectively communicating them.
https://ini2021.com/coffee-plants-have-low-nue/

15.3.1.3 Effect of conservation agriculture and integrated soil fertility management on urea nitrogen use efficiency in contrasting agro-ecological regions in Kenya (Eunice Annah Mutuku)

Eunice Annah Mutuku and colleagues from Kenya and Belgium reported the results from field experiments with maize in sub-humid and semi-arid regions of Kenya. As maize production in Kenya is on the decline attributed to low soil fertility and erratic rainfall, the application of N fertilizer is necessary. Consequences for NUE were investigated for two soil management practices, i.e. Conservation Agriculture (CA) and Integrated Soil Fertility Management (ISFM). ^{15}N labelled urea was used to determine maize grain NUE.
https://ini2021.com/effect-of-conservation-agriculture-and-integrated-soil-fertility-management-on-urea-nitrogen-use-efficiency/

15.3.1.4 Increasing nitrogen use efficiency by new designed cropping systems in an intensive agricultural region of China (Chong Zhang)

Chong Zhang and Xiaotang Ju compared the conventional winter wheat-summer maize cropping system with four cropping systems that were designed with optimized management of crop type, N, water, straw and tillage. The alternatives covered optimized winter wheat-summer maize cropping system in one year, three harvests in two years, including winter wheat–summer maize–spring maize system and winter wheat–summer soybean–spring maize, and one harvest in one year (spring maize). All field experiments were conducted in the North China Plain, the most crop productive area in East Asia. Fertilizer N use efficiency could be largely increased by adopting the new designed cropping systems.
https://ini2021.com/increasing-nitrogen-use-efficiency-by-new-designed-cropping-systems-in-an-intensive-agricultural-region-of-china/

15.3.1.5 Is Early Sowing of winter cereals as effective as Catch Crops in Increasing Nitrogen Use Efficiency in Cropping Systems? (Iris Vogeler)

Iris Vogeler and her co-workers performed a field study over three years to simultaneously evaluate the effect of early sowing of a winter cereal and the use of a catch crop in a spring barley rotation on yield, and N leaching in two areas with different climate conditions in Denmark. They measured grain yield, grain N content, and autumn N uptake in five different crop rotation types. In general, the use of catch crops, as well as early seeding of winter cereals reduced N leaching. Further long-term studies are necessary.
https://ini2021.com/is-early-sowing-of-winter-cereals-as-effective-as-catch-crops-in-increasing-nitrogen-use-efficiency-in-cropping-systems/

15.3.1.6 Assessment of required increases in nitrogen use efficiencies in agriculture to comply with water and air quality objectives in EU27 (Wim de Vries)

Wim de Vries and Lena Schulte-Uebbing presented a spatially explicit estimation of required nitrogen use efficiencies (NUEs) to attain either current crop yields and target crop yields while complying with environmental standards within EU27. The standards refer to critical nitrogen deposition levels in terrestrial ecosystems, critical nitrogen concentrations in surface water (eutrophication) and in groundwater (drinking water). They calculated the N inputs at which critical N depositions or concentrations are just not exceeded ("critical N input"). Critical N inputs are on average 41 % and 26% lower than actual N inputs in view of critical N concentrations in surface water and critical N deposition levels, respectively. Critical N inputs for groundwater quality, however, are on average 6 % higher than actual N inputs.
https://ini2021.com/assessment-of-required-increases-in-nitrogen-use-efficiencies-in-agriculture/

15.3.1.7 Improving genetical controlled crop nitrogen use efficiency (Guohua Xu)

Guohoa Xu had been invited to talk about the genetic and environmental background of variations of NUE in crops. He highlighted that each step of nitrogen uptake, translocation, assimilation, and remobilization in crops is governed by multiple interacting genetic and environmental factors. This is the reason for natural large variations of NUE among the germplasms or cultivars. He introduced the NUE evaluation of core collection germplasms and landrace cultivars of rice plants grown in paddy field supplied with different levels of N fertilizers. The results of recent research demonstrate that the back and forth between field and lab is essential for breeding future high NUE cultivars to reduce N fertilizer demand.
https://ini2021.com/improving-genetical-controlled-crop-nitrogen-use-efficiency/

15.3.1.8 Optimising Nitrogen release in an agroforestry system (Adejoke Olukemi Akinyele)

Adejoke Akinyele and Ugonma Donald-Amaechi studied the decomposition of leaf litter that produces organic matter and releases nitrogen aiming at the improvement of soil fertility for increased food production. They compared dry leaf litter from three agroforestry species. Initial nitrogen content, decay constant and half-lives were determined in more than 400 samples. Adejoke demonstrated in her talk that the species under research could be effective as source of nitrogen in an agroforestry system.
https://ini2021.com/optimising-nitrogen-release-in-an-agroforestry-system/

15.3.2 Discussion

The discussion focused on the following subjects:

- Improving NUE to meet European environment standards: Have discharges from livestock production and human waste been accounted for? What is the implication of your results for reducing N lost from non-crop sectors? How will the EU Farm-to-Fork strategy influence the N losses?
- Improving genetically controlled crop NUE: How the “high NUE cultivar” is defined? Is there a physical limit for the NUE improvement for cultivars, e.g. for rice? How far can the N surplus be reduced without penalizing yields by generalizing the cultivation of high-yield, high NUE cultivars in China?
- Optimising Nitrogen release in an agroforestry system: What about the quantity of N released from leaf litter in the field, i.e. an assessment of fertilization in kg N ha^{-1} yr^{-1}? What kind of agroforestry practices have been developed or adopted in Nigeria? If leaves from forest are removed and applied to cropland, will it have any implication on forest health?
- How much feed import can be saved in case of a reconnection of crops and animals in Denmark?
- Which barriers are expected in case of increasing the proposed mix systems in Denmark? How far are these options already implemented?
- Is there any relationship between N application and the quality of the coffee beans?
- What are the main pathways for N losses on the coffee farms?
- Which management practices are recommended to prevent the high N surplus in case of coffee farms?
- Is the level of NUE improvement related to the alternative cropping systems sufficient to address the N pollution in China?
- Will Chinese farmers adopt the new design of cropping system? Which major barriers for adoption are expected?
- There were some requests for clarification regarding the field studies in Kenya: parallel use of manure, biological fixation of N and the potential increase of NUE in the long run.
- Will other catch crops benefits (e.g organic matter contribution, microbial activity) also maintain with early sowing of rye?

15.4 Special Session Nitrogen Use Efficiency and Sustainable Nutrient Management – animal / mix

Moderator
Xin Zhang

15.4.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

15.4.1.1 A simple and easy-to-communicate framework for analyzing Nitrogen Use Efficiency (NUE) in agriculture and food systems (Lars Stoumann Jensen)

Lars Stoutmann Jensen presented the EUNEP (European Nitrogen Experts Panel) protocol which has been developed by a large group of European scientists from academia, industry and administration. This is a simple and easy-to-use framework for NUE that can be applied to agriculture and food production–consumption systems. A graphical tool was developed to interpret and communicate the results.
https://ini2021.com/a-simple-and-easy-to-communicate-framework-for-analyzing-nitrogen-use-efficiency-nue-in-agriculture-and-food-systems/

15.4.1.2 Guidance Document on NUE indicators of the International Nitrogen Management System (INMS) (Luis Lassaletta)

Luis Lassaletta mentioned many different definitions, systems, scales and approaches for NUE that hamper international understanding and interpretation of data. He introduced the INMS Guidance Document for NUE covering all aspects that were considered critical to harmonise. The Document has been signed by 46 nitrogen specialists from 19 countries. It does not only provide clear definitions and standards for measurement and calculation, but also ways to improve NUE. Thus, a harmonised indicator has been developed to be used beyond the INMS project by scientists, practitioners, and policymakers.
https://ini2021.com/guidance-document-on-nue-indicators-of-the-global-project-inms/

15.4.1.3 Indoor breeding or full-grazing dairy management? A farm system analysis of Nitrogen Use Efficiency (Philipp Löw)

Philipp Löw and co-workers investigated N balance and NUE as a function of grazing intensity on dairy farms in Northwest Germany. 30 farms were analysed in four groups according to their pasture management systems, i.e. from full grazing system to year-round stable management. Results show that the average annual N surplus tends to increase while NUE decreases from zero grazing towards full grazing. The findings of this study suggest that low to zero-pasture systems can reach higher overall NUE mainly by controlling feed intake more efficiently compared to full-grazing farms. High variance of NUE between farms of the same group indicate space for improvements. The authors also highlighted considerable differences between the mandatory nutrient balances reported by farmers according to German law and the N balances calculated in this study.
https://ini2021.com/indoor-breeding-or-full-grazing-dairy-management-a-farm-system-analysis-of-nitrogen-use-efficiency/

15.4.1.4 Modelling nitrogen use efficiency by world poultry production systems in 2050 under contrasting production and dietary scenarios (Fernando Estellés Barber)

Fernando Estellés Barber and colleagues from the Netherlands and Spain presented a model describing poultry production systems, resources consumption and production efficiencies. This model covers the feed and land demand, the N excreted and the NUE at the flock level in 2050 by world poultry production systems under different scenarios for meat and eggs demand, production performance and feed ration. According to the results obtained, poultry production in future will be only sustainable under a paradigm of moderate meat and eggs demand and improving nutrient recycling.
https://ini2021.com/modelling-nitrogen-use-efficiency-by-world-poultry-production-systems-in-2050/

15.4.1.5 Nitrogen indicators for characterizing farm performance in European case studies (Miguel Quemada)

Miguel Quemada and his colleagues used the protocol of the EU Nitrogen Expert Panel (EUNEP) for calculating NUE and N surplus indicators of 1240 farms from six European countries. They characterized farm performance for five different types and derived target values for N indicators. On average, arable farms had the lowest N input and N surplus, whereas dairy farms had the highest N surplus and the lowest N output. External effects like export of manure and production of purchased feed were considered. The authors highlighted that the conceptual diagram proposed by the EUNEP provides a framework to analyse farm performance for farmers and policy makers.
https://ini2021.com/nitrogen-indicators-for-characterizing-farm-performance-in-european-case-studies/

15.4.1.6 Nitrogen use efficiency indicators designed for the diversity of global dairy production systems (Sharon Aarons)

Sharon Aarons presented the development of N efficiency metrics for dairy farm systems by an international project team. As methods for calculating and utilising N indicators for the diversity of dairy systems globally are often inconsistent, the group aimed at an appropriate framework for reporting and interpreting of data. The method comprises all major nutrient flows, transformations and stores that occur within a dairy farm including the addition of fertilizer and other plant nutrient sources to soil, uptake by crops and pasture, animal intake as feed, partitioning to milk, increased body mass and calves, excretion in manure (urine and dung), and the managed and unmanaged recycling of manure to soils.
https://ini2021.com/nitrogen-use-efficiency-indicators-designed-for-the-diversity-of-global-dairy-production-systems/

15.4.2 Discussion

In the lively discussion, the following subjects were mentioned:

- Shall the EUNEP protocol be used as a basis for a world-wide NUE indicator?
- Can the metrics for dairy farms be applied to all systems, or should there be specific adaptations to different production systems?
- Most important drivers of variations of NUE observed for different types of farm?
- What are the similarities of NUE and Virtual Nitrogen Factors (VNF)?
- Interpretation of the results for the NUE of dairy farms with different grazing intensity?

15.5 Closing Session

Moderator
Markus Geupel

15.5.1 Presentations

All slides made available to the organizers by the speakers after the conference can be found in a cloud archive (https://clous.uba.de/index.php/s/fajgD3TCNPPJ5pe).

15.5.1.1 Notes from the organizers - summary and documentation (Markus Geupel)

Markus Geupel (German Environment Agency, UBA) emphasized the positive response from the international and national media; particularly with respect to the statement by Federal Minister Mrs. Schulze that made its way into the German national News Channels (link). Markus pointed out that the switch from a physical to a virtual conference nearly doubled the number of registered people as compared to the postponed conference in 2020. However, compared to that, the number of online attendees was on average in the line of 200 experts at the same time. Also, it was mentioned that the number of presentations and posters decreased by about 30% each as compared to INI2020. To facilitate the follow-up of the conference, pre-recorded talks will be available on the website until end of June, posters still longer. The UBA intends to document the complete INI2021. Markus Geupel reminded the auditory that there will be a special issue of ERC and ERL (see annex on Special Issue) respectively and called for the submission of full papers until 30 June. Then he gave the floor to Ms. Lilian Busse, Acting Vice-President of the UBA.

15.5.1.2 Berlin Declaration (Lilian Busse)

Lilian Busse complimented the intensive and long-standing work of the INI that resulted in some very important international resolutions and activities aiming at a sustainable management of nitrogen. She mentioned the European "Farm-to-fork strategy" as an outcome of intensive discussions at the interface between policy and science. She highlighted four key messages of the Berlin Declaration (see section Berlin Declaration) and expressed her hope that the Declaration would contribute to a decade with focus on environmental policy. The Declaration points out that better Nitrogen management is central to meet the SDGs and underlines the importance of a continuous science policy interaction. Furthermore, the Declaration encourages further regional cooperation and national activities to tackle challenges in nitrogen abatement and underpins the importance of embedding nitrogen issues in related international policy efforts such as the UN Food Systems Summit, the UNFCCC COP26 and the Kunming Biodiversity Conference COP15 – all of them in the second half of 2021.

15.5.1.3 Panel discussion with regional INI-directors (Nandula Raghuram)

The INI Chairs took the floor. At first, Nandula Raghuram thanked Ms. Busse as representative of the conference host. He emphasized her excellent interpretation of the Berlin Declaration. Vice Chair David Kanter recalled that the Secretariat had to prepare two and a half INI conferences – the cancelled INI2020, the virtual short conference in May 2020, and the virtual INI2021. They asked the INI Regional Directors for short presentations of nitrogen related problems in their areas.

- Cameron Gourley*, Oceania Centre Director, deplored the enormous environmental damage caused by reactive nitrogen compounds in Australia. Despite high nitrogen inputs and losses in the agroeconomy, fortunately the concentrations in many areas are still low.
- Tapan Adhya, INI South Asia Centre Director, mentioned pollution by reactive nitrogen molecules in all media emitted from many economic sectors. Therefore, reduction of N waste from all sources is necessary while increasing the number of harvested crops. Tapan stressed pro-active work of INI to reach this goal and highlighted the cooperation of all countries in South Asia aiming at more sustainable N management.
- Vincent Aduramigba-Modupe, INI Africa Centre Director, reminded the auditory of interesting presentations during INI2021 proving that partnerships with relevant agencies and key stakeholders are prerequisites for success. INI should form such formidable and winning teams. Further details of Vincents recommendations are documented in the annex (Closing Panel).
- Kevin Hicks, INI Europe Centre Director, welcomed a number of progressive policy initiatives by some European countries and particularly from the EU aiming at halving nitrogen waste as called for in the Colombo Declaration. He also pointed to the new taxonomy for investments that is under discussion in the EU. He announced that INI will strengthen its work in Eastern Europe and in the Caucasian region.
- Xiaotang Ju, INI East Asia Centre Director, stressed the population growth and the increasing economic importance in the East Asia region, where 9.6% of the world's arable land are cultivated but 30.2 % of the world's nitrogen fertilizer are consumed resulting in low N use efficiency. He welcomed the Berlin Declaration that will be disseminated also among the governments in East Asia.
- Osvaldo Salazar, INI Latin America Centre Director, reported N imbalances on this continent, related to intensive animal agriculture and over-fertilization, but at the same time nitrogen deficiency in other areas. At present, there is no common nitrogen policy of the governments. A jointly defined goal would be a fist successful approach.
- Claudia Wagner-Riddle, INI North America Centre Director, reported some progressive Canadian regulations and promising discussions in the United States.

15.5.1.4 Farewell by the Hosts (Markus Geupel, Stefanie Wolter)

As representatives of the hosts, Markus Geupel (German Environment Agency) and Stefanie Wolter (Federal Ministry for the Environment) closed the 8th INI Conference with special thanks to the Conference Secretariat, the INI Steering Committee, the International and the Local Advisory Committees, the Scientific Committee and the Session Chairs for their valuable cooperation and to the presenters and the participants for excellent work and discussions.

16 Virtual poster wall

In total there were 75 Posters submitted to the INI2021. They were submitted in digital form as pdf-files and are published under the INI2021 website: https://ini2021.com/posters-2021/

On the websites all files are downloadable. They are sorted according to eight overarching headlines of the conference.

In the following all posters and their authors are listed:

16.1 Theme 1b - Responsible consumption and production and feedbacks in the N cycle

Physiological Nitrogen release from human population. A case study within East Europe (Volodymyr Medinets)
https://ini2021.com/physiological-nitrogen-release/

16.2 Theme 2a - Livestock production and nitrogen Balance and nutrient cycle

Assessment of nitrogen flows at farm and regional level when developing the manure management system for large-scale livestock enterprises (Vasilev Eduard)
https://ini2021.com/assessment-of-nitrogen/

P budget calculations of German farmland and resulting manure surpluses in livestock hotspot regions (Uwe Häußermann)
https://ini2021.com/p-budget-calculations-of-german-farmland/

16.3 Theme 2a - Livestock production and nitrogen emissions

Identifying cost-effective mitigation strategies for greenhouse gas and ammonia emissions (Barbara Amon)
https://ini2021.com/identifying-cost-effective-mitigation-strategies-for-greenhouse-gas-and-ammonia-emissions/

Modelling Greenhouse Gas and Nitrogen Emissions from Ruminant Farming Systems and Influence of Feed Management Decisions on Downstream Emissions (Latifa Ouatahar)
https://ini2021.com/modelling-greenhouse-gas-and-nitrogen-emissions-from-cattle/

16.4 Theme 2b - Optimizing the efficiency of nitrogen use in crop production

Nitrogen value of prunnings of Leucaena leucocephala (Lam.) deWit, Senna siamea (Lam.) Irwin & Barneby and Enterolopium cyclocarpum (Jacq.) Griseb. (Adejoke O. Akinyele)
https://ini2021.com/nitrogen-value-of-prunnings-of-leucaena-leucocephala-lam-dewit-senna-siamea-lam-irwin-barneby-and-enterolopium-cyclocarpum-jacq-griseb/

Comparing yield, nutritional quality, water and nitrogen use efficiencies of deficit drip and flood irrigated sorghum (Sorghum bicolor) and corn (Zea mays) subjected to different nitrogen rates (R. K. Brar)
https://ini2021.com/comparing-yield-nutritional-quality-water-and-nitrogen-use-efficiencies-of-deficit-drip-and-flood-irrigated-sorghum-2/

Long-term nitrogen fertilization can increase the availability of residual phosphorus in arable soil (Jaroslav Záhora)
https://ini2021.com/delayed-n-timing-for-maize-reduced-n2o-emissions-and-drainage-2/

Delayed N timing for maize reduced N2O emissions and drainage [NO3-] while increasing yield (Peter Scharf)
https://ini2021.com/delayed-n-timing-for-maize-reduced-n2o-emissions-and-drainage/

Exploring the Impact of Nitrogen Sources on Yield, Partitioning and Nitrogen Use Efficiencies of Irrigated Lowland Rice Fields (Winnie Ntinyari)
https://ini2021.com/exploring-the-impact-of-nitrogen-sources-on-yield/

Wheat productivity at various N-levels and future predictions under changing climate (Abdul Wakeel)
https://ini2021.com/urease-inhibitor-still-active-at-low-concentration-2/

Exploring the limitations of first-order kinetics in modelling net N mineralization from plant residue at low and variable temperatures (Jorge Federico Miranda-Vélez)
https://ini2021.com/exploring-the-limitations-of-first-order-kinetics-fok-in-modelling-net-n/

Indices of crop water stress from UAV images precisely map residual nitrogen and risk of nitrate leaching spatial variability (Jan Haberle)
https://ini2021.com/indices-of-crop-water-stress-from-uav-images/

Nitrogen use efficiency of maize and cotton in 1.32 Mha of commercial farms in Brazil (Heitor Cantarella)
https://ini2021.com/nitrogen-and-water-use-efficiency-of-maize/

Algae extracts as a sustainable nitrogen-containing fertilizer (Lin Du)
https://ini2021.com/algae-extracts-as-a-sustainable-nitrogen-containing-fertilizer/

Urease inhibitor still active at low concentration (Heitor Cantarella)
https://ini2021.com/urease-inhibitor-still-active-at-low-concentration/

Effect of urease and nitrification inhibitors on N2O emissions, ammonia volatilization and crop yield in a rape crop (Mónica Montoya)
https://ini2021.com/effect-of-urease/

Nitrogen and water use efficiency of maize in long-term field experiment (Agnieszka Rutkowska)
https://ini2021.com/nitrogen-use-efficiency-of-maize-and-cotton/

Changes in nitrogen agricultural practices to increase farm sustainability - tomato production (Soraia Cruz)
https://ini2021.com/changes-in-nitrogen-agricultural-practices/

Impact of N-fertiliser reduction on agronomic parameters and quality aspects for drinking water production in Northwest-Germany (Insa Kühling)
https://ini2021.com/impact-of-n-fertiliser-reduction/

16.5 Theme 2b - Nitrifications & inhibitors; microbes

Root system architecture variability and nitrate reductase activity in wheat genotypes for nitrogen use efficiency (Aysha Kiran)
https://ini2021.com/root-system-architecture-variability-and-nitrate-reductase-activity-in-wheat/

Effect of nitrification inhibitors and soil pH on N2O emissions (Ximena Huérfano)
https://ini2021.com/effect-of-nitrification-inhibitors-and-soil-ph-on-n2o-emissions/

Changes of soil microbes related with carbon and nitrogen cycling after long-term CO2 enrichment in a typical Chinese maize field (Liping Guo)
https://ini2021.com/changes-of-soil-microbes-related-with-carbon-and-nitrogen-cycling/

1,2,3-Triazoles as Nitrification Inhibitors for Australian Soils (Bethany Taggert)
https://ini2021.com/123-triazoles-as-nitrification-inhibitors-for-australian-soils-2/

16.6 Theme 3b - Reduction of nitrogen in wastewater to ensure clean water and sanitation

Assessment of the efficiency of nitrogen removal from municipal wastewater (Monika Suchowska-Kisielewicz)
https://ini2021.com/assessment-of-the-efficiency-of-nitrogen-removal-from-municipal-wastewater-2/

16.7 Theme 4a - Threats for terrestrial Biodiversity

Effects of available nitrogen on numbers of native herbaceous plants in Aomori, Japan (Mitsuhisa Baba)
https://ini2021.com/effects-of-available-nitrogen-on-numbers-of-native-herbaceous-plants-in-aomori-japan/

16.8 Theme 4b - Threats for aquatic Biodiversity

Nitrate Leaching Potential for Drip Irrigated Cauliflower (Brassica oleracea var. Botrytis) Grown on a Sandy Loam Soil (Florence Cassel)
https://ini2021.com/nitrate-leaching-potential-for-drip-irrigated-cauliflower-2/

Reducing future nitrogen pollution in rivers of the Bay of Bengal (Masooma Batool)
https://ini2021.com/reducing-future-nitrogen-pollution-in-rivers/

Nitrate accumulation in an intensive small agricultural catchment: challenges and solutions (Jianbin Zhou)
https://ini2021.com/wp-content/uploads/2021/05/67_-Nitrate-accumulation-in_Jianbin-Zhou.pdf

Historical N load from land to East-China sea and riverine N2O emission in East-Asia (Kazuya Nishina)
https://ini2021.com/historical-n-load-from-land-to-east-china-sea-and-riverine-n2o-emission-in-east-asia/

Context is everything: what controls nitrogen concentrations in U.S. streams (Jana Compton)
https://ini2021.com/context-is-everything-what-controls-nitrogen-concentrations-in-u-s-streams/

Nutrient enrichment changes water transport structures of savanna woody plants in Brazil (Lucas Silva Costa)
https://ini2021.com/nutrient-enrichment-changes-water-transport-structures/

Regionalized nitrogen fate in freshwater systems on a global scale (Jinhui Zhou)
https://ini2021.com/wp-content/uploads/2021/05/231_Regionalized-nitrogen-fate_Jinhui-Zhu.pdf

Simulating 50 years of land management and groundwater flow to explain today's nitrate concentrations in Flemish surface waters (Jeroen De Waele)
https://ini2021.com/simulating-50-years-of-land-management-and-groundwater-flow/

16.9 Theme 5b - Biogeochemical N Cycle

National nitrogen budget for Germany (Uwe Häußermann)
https://ini2021.com/national-nitrogen-budget-for-germany/

Nitrogen budget estimation in the East Europe: A case study for Dniester and Prut catchments (Sergiy Medinets)
https://ini2021.com/nitrogen-budget-estimation-in-the-east-europe-a-case-study-for-dniester-and-prut-catchments-2/

Assessment of Nitrogen and Carbon compounds emission as aftermath of wildfires in Dniester Delta (Ukraine) in 2010-2019 (Volodymyr Medinets)
https://ini2021.com/assessment-of-nitrogen-and-carbon-compounds-emission-as-aftermath-of-wildfires-in-dniester-delta/

Temporal dynamics of reactive nitrogen fluxes over different ecosystems (Christian Brümmer)
https://ini2021.com/temporal-dynamics-of-reactive-nitrogen-fluxes-over-different-ecosystems/

The potential of ryegrass as cover crop to reduce soil N_2O emissions and increase the population size of denitrifying bacteria (Haitao Wang)
https://ini2021.com/the-potential-of-ryegrass-as-cover-crop-to-reduce-soil-n2o-emissions/

Variability of atmospheric ammonia and its sources over Indian region (Saumya Singh)
https://ini2021.com/variability-of-atmospheric-ammonia-and-its-sources-over-indian-region/

Characterization of Atmospheric Reactive Nitrogen Emissions from Global Agricultural Soils (Viney Aneja)
https://ini2021.com/characterization-of-atmospheric-reactive-nitrogen-emissions-from-global-agricultural-soils/

Characterization of reactive nitrogen emissions from turfgrass systems (Viney Aneja)
https://ini2021.com/characterization-of-reactive-nitrogen-emissions-from-turfgrass/

Reactive Nitrogen Flows Between Sector Energy and Transport and the Atmosphere in the EE Demoregion (Lidiya Moklyachuk)
https://ini2021.com/assessment-of-nitrogen-and-carbon-compounds-emission/

Impact of climate change on nitric oxide and nitrous oxide emission from typical landuses in Scotland (Sergiy Medinets)
https://ini2021.com/impact-of-climate-change-on-nitric-oxide-and-nitrous-oxide-emission/

Oxygen regulates nitrous oxide production directly in agricultural soils (Xiaotong Song)
https://ini2021.com/oxygen-regulates-nitrous-production-directly-in-agricultural-soils/

Nitrous oxide emissions from Soddy podzolic sandy loam soil after long-term fertilizer and manure application (Natalia Buchkina)
https://ini2021.com/nitrous-oxide-emissions-from-soddy-podzolicsandy-loam-soil/

The global distribution of soil nitrification and the fraction of associated N2O emission by using stochastic gradient boosting models (Baobao Pan)
https://ini2021.com/the-global-distribution-of-soil-nitrification/

An open-path quantum cascade laser (QCL) based ammonia analyzer for eddy covariance flux measurement (Yin Wang)
https://ini2021.com/an-open-path-quantum-cascade-laser-based-ammonia-analyzer/

Dominant contribution of nitrogen compounds in precipitation chemistry in the lake Victoria catchment (East Africa) (Adama Bakayoko)
https://ini2021.com/dominant-contribution-of-nitrogen-compounds-in-precipitation/

High-resolution ammonia emission Inventory in Belarus (Hanna Malchykhina)
https://ini2021.com/high-resolution-ammonia-emission-inventory-in-belarus/

Validation of nitrogen dry deposition modelling above forest using high-frequency flux measurements (Pascal Wintjen)
https://ini2021.com/validation-of-nitrogen-dry-deposition-modelling-above-forest/

Long-term atmospheric inorganic nitrogen deposition in West African savanna over 16 year period in Lamto, Côte d'Ivoire (Money Guillaume Ossohou)
https://ini2021.com/dominant-contribution-of-nitrogen-compounds/

16.10 Theme 6a - Closing the N cycle: Innovations for sustainable N management

Alternative fertilizers from nutrient-rich wastes for organic crops (Beatriz Gómez-Muñoz)
https://ini2021.com/alternative-fertilizers-from-nutrient-rich-wastes-for-organic-crops-2/

Ammonium volatilization from urea and its inhibition by urease inhibitor Limus: Methods for sensual perception as tools to foster environmental awareness (Alexander Wissemeier)
https://ini2021.com/ammonium-volatilization-from-urea-and-its-inhibition-by-urease-inhibitor-limus/

N_2O, N_2 and NH_3 emissions following different slurry and digestate application techniques in growing crops (Caroline Buchen-Tschiskale)
https://ini2021.com/n2o-n2-and-nh3-emissions-following-different-slurry-and-digestate-application-techniques/

NIRS sensing for organic fertilizers: A chance for an efficient manure management in the EU? (Jörg Rieger)
https://ini2021.com/alternative-fertilizers-from-nutrient-rich-wastes-for-organic-crops/

Sensor technologies for detection of urine patches in livestock-grazed pastures (Jiafa Luo)
https://ini2021.com/sensor-technologies-for-detection-of-urine-patches-in-livestock-grazed-pastures-2/

Design of biodegradable polymer coatings for controlled nutrient release from organic fertilizers (Evelien Vermoesen)
https://ini2021.com/development-of-biodegradable-polymers/

Liquid Swine Manure Nitrogen Conservation and Concentration Technology (Alison Deviney)
https://ini2021.com/liquid-swine-manure-nitrogen-conservation-and-concentration-technology/

Detection of nitrogen in winter wheat based on Sentinel-2 data (Gretelerika Vindeker)
https://ini2021.com/detection-of-nitrogen-in-winter-wheat-based-on-sentinel-2-data/

16.11 Theme 7a - From Science to Policy

Cost curves for ammonia mitigation measures in German livestock systems (Uwe Häußermann)
https://ini2021.com/cost-curves-for-ammonia-mitigation-measures-in-german-livestock-systems/

Challenges facing N-regulation in Germany, The Netherlands and Denmark (Brian H. Jacobsen)
https://ini2021.com/challenges-facing-n-regulation-in-germany-the-netherlands-and-denmark/

Nr management in current Brazilian policies (Gisleine Cunha-Zeri)
https://ini2021.com/nr-management-in-current-brazilian-policies/

16.12 Theme 7b - Educational aspects, public awareness, risk communication

Communicating consequences of excess nitrogen. Short films for social media linking nitrogen and sustainable development goals (Joyce-Ann Syhre)
https://ini2021.com/communicating-consequences-of-excess-nitrogen-short-films-for-social-media-linking-nitrogen-and-sustainable-development-goals-2/

Citizen dialogue on policy instruments for the reduction of reactive nitrogen in Germany (Jörn Hamacher)
https://ini2021.com/citizen-dialogue-on-policy-instruments-for-the-reduction-of-reactive-nitrogen-in-germany-2/

Measures and scenarios for the implementation of the reduction targets set by the NEC directive (Uwe Häußermann)
https://ini2021.com/measures-and-scenarios-for-the-implementation-of-the-reduction-targets-set-by-the-new-nec-directive/

16.13 Special Session on Nitrogen Footprints

The US nitrogen footprint: An updated approach and comparison (Allison Leach)
https://ini2021.com/the-us-nitrogen-footprint-an-updated-approach-and-comparison-2/

Indonesian Nitrogen Footprint Assessment of Food Sector (Farah Wirasenjaya)
https://ini2021.com/indonesian-nitrogen-footprint-assessment-of-food-sector/

The Portuguese nitrogen footprint, a challenge in a Mediterranean country (Cláudia Marques dos Santos Cordovil)
https://ini2021.com/the-portuguese-nitrogen-footprint-a-challenge-in-a-mediterranean-country/

Nitrogen footprint calculator for Germany (Laura Klement)
https://ini2021.com/nitrogen-footprint-calculator-for-germany/

A nitrogen footprint perspective for Brazilian water sector (Camille Nolasco)
https://ini2021.com/a-nitrogen-footprint-perspective-for-brazilian-water-sector/

Reducing the nitrogen footprint of Portuguese wine (Soraia Cruz)
https://ini2021.com/reducing-the-nitrogen-footprint-of-portuguese-wine/

Nitrogen footprint of protein-free products (Kentaro Hayashi)
https://ini2021.com/nitrogen-footprint-of-protein-free-products/

A Nitrogen Footprint Tool for Communities: A Case Study for Baltimore, MD, USA
(Elizabeth Dukes)
https://ini2021.com/a-nitrogen-footprint-tool-nft-for-communities/

17 Annex

17.1 Special Issue

A Focus Collection of important contributions to INI2021 was published in Environmental Research Communication and Environmental Research Letters (IOP). The guest editors (mostly members of the International Advisory Committee to INI2021) selected a number of manuscripts for peer-review according to the standards of each journal. The papers of the Focus Collection are freely accessible (open access) under the following link:
https://iopscience.iop.org/journal/1748-9326/page/Focus_on_Reactive_Nitrogen

17.2 Attachment to the Berlin Declaration

Important papers dealing with reactive nitrogen compounds recommended by the International and the Local Advisory Board

17.2.1 International Bodies and Conferences

UNEA4: Sustainable Nitrogen Management (UNEP/EA.4/L.16)
(https://sdg.iisd.org/news/unea-4-calls-for-strengthened-approach-to-sustainable-nitrogen-management/)

Colombo Declaration
(https://www.unep.org/news-and-stories/press-release/colombo-declaration-calls-tackling-global-nitrogen-challenge;
https://web.archive.org/web/20200812202815/https://papersmart.unon.org/resolution/node/286/)

European Commission: Towards Zero Pollution for Air, Water and Soil
(https://ec.europa.eu/environment/strategy/zero-pollution-action-plan_de)

17.2.2 Statements of INI Global Conferences

Delhi Declaration on Reactive Nitrogen Management for Sustainable Development
(Delegates of the 5th International Nitrogen Conference, Delhi, 2011)
http://lacs.ipni.net/ipniweb/region/lacs.nsf/0/F1B3C2541A5FC9F9032579030053FB3A/$FILE/Delhi Declaration N2010.pdf

The Kampala Statement-for-Action on Reactive Nitrogen in Africa and Globally
(Just enough Nitrogen, p- 583-593. Eds.: Mark A. Sutton, Peter Ebanyat, N. Raghuram, Mateete Bekunda, John S. Tenywa, Wilfried Winiwarter, Albert Bleeker, Eric A. Davidson, Jan Willem Erisman, Wim de Vries, James N. Galloway, Patrick Heffer, W. Kevin Hicks, Cargele Masso, Cheryl A. Palm, Clifford S. Snyder, Bernard Vanlauwe, Shamie Zingore, Delegates of the 6th International Nitrogen Conference, Kampala, Springer 2020)
https://link.springer.com/chapter/10.1007/978-3-030-58065-0_38

Melbourne Declaration on Responsible Nitrogen Management for a Sustainable Future
(Delegates of the 7th International Nitrogen Conference, Melbourne 2016;
https://www.ini2016.com/melbourne-declaration/)

17.2.3 Reports – scientific basis of nitrogen management

Reactive Nitrogen in the Environment. Too Much or Too Little of a Good Thing
(Ed.: UNEP 2007, ISBN: 978 92 807 2783 8)

Nitrogen Pollution and the European Environment. Implications for Air Quality Policy
(ed.: European Commission, 2013)

Principles of integrated, sustainable nitrogen management
(Ed.: UNECE Task Force on Reactive Nitrogen, 2019) Draft

NITROGEN: Strategies for resolving an urgent environmental problem
(Ed.: German Advisory Council on the Environment, 2015)
https://www.umweltrat.de/SharedDocs/Downloads/EN/02_Special_Reports/2012_2016/2015_01_Nitrogen_Strategies_summary.html

17.2.4 Scientific papers

Pattanun Achakulwisut, Michael Brauer, Perry Hystad, Susan C Anenberg**:**
Global, national, and urban burdens of paediatric asthma incidence attributable to ambient NO2 pollution: estimates from global datasets; The Lancet Planetary Health 3 (4) 166-178 (2019)

Geupel, Markus; Heldstab, Jürg; Schäppi, Bettina; Reutimann, Judith; Bach, Martin; Häußermann, Uwe; Knoll, Lukas; Klement, Laura; Breuer, Lutz. 2021.
A National Nitrogen Target for Germany. Sustainability 13, no. 3: 1121.
https://doi.org/10.3390/su13031121

B. Grizzetti, O.Vigiak ,A.Udias ,A.Aloe, M.Zanni, F.Bouraoui, A.Pistocchi, C.Dorati, R.Friedland, A. De Roo, C. Benitez Sanz, A. Leip, M. Bielz:
How EU policies could reduce nutrient pollution in European inland and coastal waters.
Global Environmental Change 69 (July 2021) 102281

Gu B J, Ju X T, Chang J, Ge Y, Vitousek P M 2015.
Integrated reactive nitrogen budgets and future trends in China.
Proceedings of the National Academy of Sciences of the United States of America[J], 112: 8792-8797.

Gu B J, Song Y, Yu C Q, Ju X T 2020.
Overcoming socioeconomic barriers to reduce agricultural ammonia emission in China.
Environmental Science and Pollution Research[J], 27: 25813-25817.

Peijue Huangfu, Richard Atkinson:
Long-term exposure to NO2 and O3 and all-cause and respiratory mortality: A systematic review and meta-analysis;
Environment International 144 (2020) 105998

Ju X T, Gu B J, Wu Y Y, Galloway J N 2016.
Reducing China's fertilizer use by increasing farm size.
Global Environmental Change-Human and Policy Dimensions[J], 41: 26-32.

Ju X T, Xing G X, Chen X P, Zhang S L, Zhang L J, Liu X J, Cui Z L, Yin B, Christie P, Zhu Z L, Zhang F S 2009.
Reducing environmental risk by improving N management in intensive Chinese agricultural systems.
Proceedings of the National Academy of Sciences of the United States of America[J], 106: 3041-3046.

Adrian Leip, Susanna Kugelberg, Benjamin Bodirsky (eds).:
Managing nutrients: the key to achieve sustainable food systems for healthy diets; Global Food Security, Special Issue,
https://www.sciencedirect.com/journal/global-food-security/special-issue/10658FVGSC6

Rajen N. Naidoo:
NO_2 increases the risk for childhood asthma: a global concern.
The Lancet Planetary Health 3 (4) 155-156 (2019)
http://dx.doi.org/10.1016/S2542-5196(19)30059-2

Norse D, Ju X T 2015.
Environmental costs of China's food security.
Agriculture Ecosystems & Environment[J], 209: 5-14.

Pablo Orellano, Julieta Reynoso, Nancy Quarantac, Ariel Bardach, Agustin Ciapponi:
Short-term exposure to particulate matter (PM10 and PM2.5), nitrogen dioxide (NO_2), and ozone (O_3) and all-cause and cause-specific mortality: Systematic review and meta-analysis;
Environment International 142 (2020) 105876

Nandula Raghuram, Mark A. Sutton, Roger Jeffery, Ramesh Ramachandran, Tapan K. Adhya:
From South Asia to the world: embracing the challenge of global sustainable nitrogen management;
One Earth 4 (January 22, 2021), 22-27

Alberto Sanz-Cobena, Roberta Alessandrini, Benjamin Leon Bodirsky, Marco Springmann, Eduardo Aguilera, Barbara Amon, Fabio Bartolini, Markus Geupel, Bruna Grizzetti, Susanna Kugelberg, Catharina Latka, Xia Liang, Anna Birgitte Milford, Patrick Musinguzi, Ee Ling Ng, Helen Suter, Adrian Leip:
Research meetings must be more sustainable, Nature Food 1, 187–189 (2020);
https://www.nature.com/articles/s43016-020-0065-2

Mark A. Sutton, Clare M. Howard, David R. Kanter, Luis Lassaletta, Andrea Móring, Nandula Raghuram, Nicole Read: **The nitrogen decade: mobilizing global action on nitrogen to 2030 and beyond**, One Earth 4 (1), 10-14 (2021); https://doi.org/10.1016/j.oneear.2020.12.016

Davy Vanham, Adrian Leip:
Sustainable food system policies need to address environmental pressures and impacts: The example of water use and water stress,
Science of the Total Environment, 730, 2020, p. 139151, JRC118605

Zhang C, Ju X T, Powlson D, Oenema O, Smith P 2019.
Nitrogen Surplus Benchmarks for Controlling N Pollution in the Main Cropping Systems of China. Environmental Science & Technology[J], 53: 6678-6687.

Xue-yan Zheng, Pablo Orellano, Hua-liang Lin, Mei Jiang, Wei-jie Guan:
Short-term exposure to ozone, nitrogen dioxide, and sulphur dioxide and emergency department visits and hospital admissions due to asthma: A systematic review and meta-analysis;
Environment International 150 (2021) 106435

17.2.5 Miscellanous

Cercedilla manifesto: Research meetings must be more sustainable (Open Petition);
https://www.openpetition.eu/petition/online/cercedilla-manifesto-research-meetings-must-be-more-sustainable

17.3 Committees

17.3.1 Local Advisory Committee

Prof. Dr. Barbara Amon, Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Germany, University of Zielona Góra, Poland / Dr. Klaus Arzet, Bavarian Ministry of Environment and Consumer Protection Department of Water Management and Soil Protection National and international River Basin Management, Germany / Dr. Benjamin Bodirsky, Potsdam Institute for Climate Impact Research, Germany / Prof. Dr. Martin Diekmann, Universität Bremen FB 02 Institut für Ökologie, Germany / Prof. Dr. Barbara Hoffmann, Universität Düsseldorf, Institut für Arbeits-, Sozial- und Umweltmedizin, Germany / Dr. Henning Meesenburg, Nordwestdeutsche Forstliche Versuchsanstalt, Germany / Dipl.-Ing. Bernhard Osterburg, Johann Heinrich von Thünen-Institut, Germany / Dr. Markus Salomon, Sachverständigenrat für Umweltfragen, Germany / Dr. Wolfgang Sprenger / Bayer. Landesamt für Umwelt, Germany / Prof. Dr. Friedhelm Taube, Univ. Kiel, Inst. für Pflanzenbau u. Pflanzenzüchtung, Germany / Prof. Dr. Maren Voss, Leibniz-Institut für Ostseeforschung Warnemünde, Germany

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17.3.3 Scientific Committee

Prof. Dr. Tapan Adhya (see above) / Prof. Dr. Barbara Amon (see above) / Dr. Klaus Arzet (see above) / Dr. Martin Bach, University of Giessen, Germany / Dr. Sabine Banzhaf, Freie Universität Berlin, Germany / Johannes Biala, Director, Centre for Recycling of Organic Waste & Nutrients (CROWN), University of Queensland, Australia / Dr. Benjamin Bodirsky (see above) / Dr. Christian Brümmer, Johann Heinrich von Thünen Institut, Germany / Dr. Peter Bruckmann, Germany / Dr. Tom Bruulsema, International Plant Nutrition Institute, Canada / Dr. Marijana Curcic, University of Belgrade, Serbia / Prof. Dr. Martin Diekmann (see above) / Dr. Ulrike Döring, German Environment Agency, Germany / Andreas Eisold, German Environment Agency, Germany / Prof. Dr. Jan Willem Erisman (see above) / Prof. Dr. Henning Friege, Leuphana University, Germany / Nils Friege, Düsseldorf District Government, Germany / Prof. Dr. Jim Galloway, University of Virginia, USA / Markus Geupel, German Environment Agency, Germany / Prof. Dr. Cameron Gourley (see above) / Patrick Heffer, International Fertilizer Organisation, France / Dr. Kevin Hicks (see above) / Falk Hilliges, German Environment Agency, Germany / Prof. Dr. Barbara Hoffmann (see above) / Dr. Max Hofmeier, German Environment Agency, Germany / Prof. Dr. Xiaotang Ju (see above) / Prof. Dr. Alexander Kekulé, University of Halle, Germany / Dr. Till Kuhn, University of Bonn, Germany / Dr. Luis Lassaletta, Universidad Popular de Madrid, Spain / Adrian Leip (see above) / Prof. Dr. Borhane Mahjoub, Ministry of Higher Education and Scientific Research, Tunisia / Dr, Henning Meesenburg (see above) / Prof. Dr. Jean Ometto (see above) / Bernhard Osterburg (see above) / Dr. Barbara Navé, BASF, Germany / Stephan Nordmann, German Environment Agency, Germany / Dr, Malte Oehlmann, adelphi, Germany / Dr. Anne-Katrin Prescher, Johann Heinrich von Thünen Institut, Germany / Dr. Andreas Prüeß, Landesanstalt für Umwelt Baden-Württemberg, Germany / Simone Richter, German Environment Agency, Germany / Dr. Markus Salomon (see above) / Dr. Alberto Sanz Cobena, Universidad Popular do Madrid, Spain / Lisa Schlesinger, German Environment Agency / Dr. Frederik Schrader, Johann Heinrich von Thünen Institut, Germany / Dr. Wolfgang Sprenger, Bayer. Landesamt für Umwelt, Germany / Prof. Dr. Friedhelm Taube (see above) / Dr. Hans von Grinsven, PBL Netherlands Assessment Agency, The Netherlands / Prof. Dr. Maren Voß (see above) / Dr. Gabriele Wechsung, German Environment Agency / Prof. Dr. Wilfried Winiwarter (see above) / Prof. Dr. Alexander Wissemeier, BASF, Germany / Dr. Stefanie Wolter, Federal Ministry for Environment, Nature Conservation and Nuclear Safety, Germany / Prof. em. Dr. Dr. Reinhard Zellner, University of Duisburg-Essen / Asst. Prof. Dr. Xin Zhang, University of Maryland Center for Environmental Science, USA.

17.3.4 Organizing Committee / INI 2021 Conference Secretariat

Markus Geupel, Lisa Schlesinger, Simone Richter (German Environment Agency) / Dr. Stefanie Wolter (Federal Ministry for the Environment, Nature Protection and Nuclear Safety) / Dr. Henning Friege (N^3 Thinking Ahead Dr. Friege & Partners) / Svenja Jürgens, David Obladen (Akademie Dr, Obladen), all from Germany

17.4 Questions and answers documented and provided in written form after the conference

17.4.1 Key-Note Session 2

17.4.1.1 Answers provided by Harold van Es

Question: Do we need a new metrics e.g. rather than yield per kg N moving to yield per kg N loss?

Answer: I agree that in principle a metric that relates yield to environmental losses would be good. The challenge would be to estimate the losses. We can do that with models like Adapt-N, but this requires a broader buy-in on the model-based estimates. I have found that many prefer simple, but often incorrect estimates over better model-simulated ones (like the IPCC estimates for nitrous oxide emissions related to N rate). The more traditional metric of yield per kilogram of nitrogen is easier to calculate, but has a lot of inherent problems when dealing with more complex systems. It makes sense when most of the nitrogen nutrition for the crop is derived from fertilizer, but when manure, cover crops, etc. are involved, this becomes problematic.

Question: Does the model show how N abatement leads to reduced optimal input rates?

Answer: Yes, the model accounts for all nitrogen inputs, including organic matter mineralization, rotations with legumes, manure and compost, etc. When a farmer uses practices that build soil health and soil organic carbon, the model can incorporate that into an N recommendation. This is why I believe it is important to start adopting more sophisticated nitrogen recommendation tools in the context of multi-objective production environments (profit, reduce nutrient losses, soil health, soil organic carbon).

Question: An N surplus of 50-80 kg N ha^{-1} yr^{-1} on global arable land (~1.5 Mha) implies a total N surplus around 75-120 Tg N yr^{-1} globally. This is quite a bit above the ~60 Tg N yr^{-1} widely cited as a planetary boundary.

Answer: This is an interesting comment. We have not done these types of calculations. In our case, we derived the safe operating space for N surplus by determining the inflection points for N losses as a function of N rate. Since the system is "leaky", the value is obviously greater than zero. But we also showed in our analyses (the second to last slide of my deck), that using a computational data-driven tool like Adapt-N allows us to achieve average N surplus of around 30 kg ha^{-1} with in-season management, and this is achieved without compromising yields. A key strategy, in my view, is to tailor the nitrogen management to the local production environment (soil, management practices, weather, etc.). This allows us to achieve our sustainability goals, and reduce the need for one-size-fits-all directives. The N Balance concept fits well with the precision management approach, i.e., setting N-Balance based performance standards will drive farmers to use better N management tools.

Question: On what do you base your simulations, how did adjust the model? And in terms of weather influencing losses, can give the farmers day-by-day recommendations?

Answer: I did not have time to go into details around the model, but it is described in our publications. Basically it is a soil biogeochemical model combined with a crop model, and uses daily high-resolution weather data. So, yes, the recommendations are adjusted on a day-by-day basis. There are a lot more components, like risk and economic factors, that are also essential for generating a recommendation.

Question: Why not disputing the potential of high tech - big data EONR to solve the agric. N pollution can it deliver enough and in time, as compared to 4 T approach (keynote Kanter) and combine N extensification and reduction protein demand?

Answer: I believe that both approaches should be pursued. There are some big picture global structural issues that contribute to the problem, but there are also issues around specific production regions. Using digital agriculture approaches allows us to make immediate gains and can significantly reduce environmental impact in many production regions. But I agree that the larger structural issues also need to be addressed, but they will take much longer. In terms of economics, the digital agriculture technologies generally provide a win-win outcome (farmer increases profits and environmental impacts are reduced). #Changing the structure of agriculture may involve more economic trade-offs and may work against market forces. It will take a lot more work to achieve progress in that area, although that should not dissuade us from pursuing it.

17.4.1.2 Answers provided by Till Spranger

Question: Is slurry application a bigger problem than chemical fertilizer application? Shouldn't the application of chemical fertilizer be reduced to allow for more slurry application?

Answer: The role of mineral vs. organic fertilizers in reactive nitrogen fluxes varies strongly between different regions/countries. The main direct fluxes affected are ammonia and nitrate emissions from agricultural soils. Taking ammonia emissions from Germany as an example: In 2019, ammonia emissions from mineral fertilizer application were responsible for ca. 12% of total national ammonia emissions. Emissions from the field application of slurry and other animal based fertilizers were responsible for ca. 29% of total emissions; an additional 10% came from plant digestates from the biogas industry. To be complete, one has to take into account that 41% of the emissions come from animal housing and slurry storage. The shares in nitrate emissions caused by mineral vs organic fertilizer application to fields will be different but similar. So - while emissions from organic fertilizers are quantitatively much more important (especially when also considering housing and storage), a reduction of the net external input into the agricultural system, e.g. via mineral fertilizers, is needed to reduce emissions. Whether this increase in N_r recycling can be better achieved by increased organic fertilizer use, reducing feed imports and / or mineral fertilizers and / or increasing N_r outputs via agricultural products depends strongly on the system.

Question: Are there research programmes open from your Ministry in Germany to support research in evaluating the N emissions from non-agriculture sources?

Answer: A large number of research projects on non-agricultural emissions (mainly NO_x, particulates and N_2O to air, various N_r compounds to water) from non-agricultural sources have been performed and are ongoing with funding from the Environment Ministry, the German Environment Agency (UBA) and other ministries. For an overview, please visit the English versions of the websites of the agency (www.umweltbundesamt.de/en/) and the ministry (www.bmu.de/en/). For specific project related questions, please contact ufoplan@uba.de or forschung@bmu.bund.de.

Question: Great about the new German Goal to reduce N waste by 30% 2015 to 2030. Can you explain why Germany selected this ambition level?

Answer: The methodology to derive the overall reactive nitrogen target is rather intricate. In a nutshell, the partial N_r fluxes in the base year allocated to various N_r-caused effects (e.g. emissions of NH_3 and NO_x to air causing eutrophication of ecosystems) are compared with values for 2030 which would result from the implementation of primarily policy-based targets (such as the respective national emission reduction commitments). These are aggregated (based on indicators, while avoiding double-counting) into one total N_r base value and 2030 target. The resulting values are approximately 1500 Gg yr^{-1} in 2015 and approximately 1000 Gg yr^{-1} in 2030, i.e. ca. -33%. Please note that spatial variation of emissions and effects indicators are largely not accounted for, so the national target does not guarantee that the effect indicator values aimed for are attained everywhere. In addition, the target does not guarantee a sustainable Nr status (e.g. full attainment of critical loads) in the target year, but only a partial attainment (i.e. -35% reduction of critical load exceedance). It should therefore be rather seen as an interim target for policy communication. For a detailed description of the approach, please see Markus Geupel´s presentation in section 7b (policy) "A National Nitrogen Target for Germany", as well as presentations by Bettina Schäppi and colleagues.

17.4.2 Key-Note Session 3

17.4.2.1 Answers provided by Stefanie Wolter

Question: Did the dialogues help to bridge the contrasting view of urbans and farmers on a less N intensive - N polluting agriculture?

Answer: In the dialogs we tried to get a representative (for Germany) mixture of age, sex and educational level. It was not possible to make stakeholders as farmers join explicitly. If this is your target you must try to bring both parties to one table.

Question: How do you propose to communicate with the fertilizer industries?

Answer: I have no strategy so far to include the fertilizer industry in particular. My focus goes more in the direction of farmers, i.e. users, than of the producers of fertilizer.

17.4.3 Closing Panel

17.4.3.1 Vincent Aduramigba-Modupe, INI Africa Centre Director

17.4.3.1.1 The current state of N-agenda in Africa - assessment, policy attention

Africa has the 12th highest population growth rates in the world, which may double by 2050. A critical challenge facing crop production in the continent is the low nitrogen in many ecosystems, with profound implication on productivity. Africa, have bio-physical constraints which impinge on development, and need to be addressed. Most research conducted by scientists in the continent are rarely used in decision-making, because they are not properly aligned with the needs of decision-makers due to weak linkage between science and policy.

17.4.3.1.2 African region perspective on this conference - hits and misses

Interwoven N challenges were tackled through scientific advances and deliberate partnership resulting in a new paradigm shift. Successful partnerships with relevant agencies and key stakeholders in Germany and beyond, was a *key lesson that in partnering with key institutions, we will build a formidable and winning team.* Need to lobby developmental partners to invest more in R&D for participants from Africa to be more visible, Germany should lead using the experiences gathered from INI2021.

17.4.3.1.3 My outlook for the future of N management in Africa region

Promote transfer of globally proven best fit N technologies (from the field to the marketplace) that are environmentally sound, technically appropriate, economically viable and socially acceptable to Africans. This will result in meeting the ambitious goal of the SDGs that have to do with N resulting in improved nutrition and livelihoods. Successful partnerships with key agencies, research institutions and stakeholders in Africa and beyond.

INI Africa together with the global N community, fully support the Berlin declaration, and will disseminate the achievements of this conference, to stakeholders and policy institutions in our region.

18 Feedback Survey Evaluation

After the conference the hosts and the organisers asked for participants' experiences. The evaluation of the survey can be found here:

https://survey.zohopublic.eu/zs/report/r6hViN.

The results are an important input for the preparation of future global conferences. For example, 75 % of the participants stated, that future scientific conferences after the pandemic should allow both, personal and virtual attendance as an option. Largest disadvantage that was seen in the virtual format of INI2021 was the poor ability for networking. On the other hand, the largest advantage was seen in the improved sustainability of the virtual format and the reduction of emissions connected to the travelling.