August 7, 2025

Chair Joaquin Esquivel and Members of the Board
State Water Resources Control Board
c/o Courtney Tyler, Clerk of the Board
1001 “I” Street, 24th Floor
Sacramento, CA 95812

Re: Establishing Numeric Limits on Nitrogen Discharges from Irrigated Agriculture

Dear Chair Esquivel and Members of the State Water Resources Control Board:

The undersigned groups write to urge the State Water Resources Control Board (Water Board or the Board) to develop numeric limits on nitrogen applications and discharges to improve the Irrigated Lands Regulatory Program and protect water quality objectives statewide. Despite efforts by the Water Board, excessive fertilizer use and its associated nitrogen pollution continue to sicken people, threaten biodiversity, and contribute to climate change. The Water Board has an obligation and the authority to protect communities, ecosystems, and the climate by adopting numeric limits on fertilizer overapplication. As detailed in a literature review shared with Water Board staff on July 31, 2025 (a copy of which is attached to this letter), other countries have successfully established science-based limits on nitrogen fertilizers that have improved water quality. California can learn from their examples and lead the nation in combating nitrogen pollution.

Nitrogen pollution continues to harm people, ecosystems, and the climate

The harm to people of nitrogen pollution is well-known. Excessive fertilizer use causes nitrates to leach into drinking water supplies, causing infants to suffer and sometimes die from being unable to maintain sufficient oxygen levels (known as "blue baby" syndrome).[1] Between 2011 and 2019, an estimated 1,730 cases of blue baby syndrome were reported in California, primarily clustered in Central Valley regions with elevated nitrates in well water.[2] Nitrate contamination is also associated with higher rates of leukemia, lymphoma, and childhood brain cancers.[3] Currently, nearly one million Californians do not have access to safe drinking water. At least 87 community water systems exceed the 10 mg/L maximum contaminant level for nitrate.[4] According to the Board's 2025 Safe Drinking Water Needs Assessment Report, there has been a 26% *increase* in the number of domestic wells that are at risk of failing to provide safe drinking water from the previous year.[5] Most of the people at risk of drinking contaminated water live in disadvantaged communities.[6]

Excessive fertilizer use contributes to climate change and air pollution. According to the California Nitrogen Assessment, most high value crops use an average of 24 percent of the fertilizer applied,[7] which means that most is lost to the environment. When fertilizer is overapplied to a crop, the excess fertilizer enters the air as nitrous oxide (N_2O), a greenhouse gas that is almost 300 times more potent than carbon dioxide.[8] 60 percent of California's total nitrous oxide emissions are caused by agricultural activities.[9] The California Air Resources Board notes in its 2022 Scoping Plan that California will not meet its climate goals without significantly reducing agricultural nitrous oxide emissions.[10] Nitrous oxide emissions also deplete the ozone layer, causing people to suffer from skin cancers and cataracts.[11]

Nitrogen pollution also degrades ecosystems, poisons wildlife, and diminishes biodiversity. When nitrogen runs off into fresh water, it contributes to cyanobacteria and harmful algal blooms (HABs), which can result in fish die-offs, sick pets, and children with blisters and rashes from swimming in an affected river.[12] HABs also compromise recreational and fishing economies, costing millions to clean up and remedy.[13] The harms from HABs are particularly acute for Indigenous communities who rely on healthy marine and freshwater ecosystems for sustenance, income, and cultural practices.[14] Nitrogen pollution threatens up to 78 imperiled species throughout the United States, including California species like the Bay checkerspot butterfly and arroyo toad.[15]

The Water Board has the authority and opportunity to set limits on fertilizer overapplication and discharge

The Water Board's Irrigated Lands Regulatory Program (Program) was designed to protect water quality by reducing nitrogen pollution. The Program's sole emphasis on non-numeric requirements (i.e. reporting, education, management practice evaluation, and outreach) has not improved water quality, and in some parts of the state, water quality has worsened.[16] The Water Board can and should strengthen the Program by setting numeric limits on nitrogen applications and discharges.

The Program already requires farmers to report their application of nitrogen fertilizers, which is a critical first step in understanding the scale of fertilizer overapplications. In Agricultural Order 4.0 (R3-2021-0040), the Central Coast Regional Water Quality Control Board (Central Coast Board) used all its farmer-reported data to develop common sense nitrogen-related targets and limits because they observed that data reporting, encouragement to improve management practices, and education were not improving water quality in their region.[17] In their supporting documents, the Central Coast Board provided analysis demonstrating that progressively reduced targets and limits[18] would ultimately ensure wells met safe drinking water standards for their region.[19] Now the Board has requested that a second Statewide Agricultural Expert Panel examine the data collected through the all the regional boards' Irrigated Lands Regulatory Programs and recommend improvements.[20] The Water Board can dramatically reduce nitrogen pollution and maintain a healthy agricultural economy by setting numeric limits on fertilizer applications and discharge.[21]

The Water Board also has a responsibility to assist regional boards in achieving their water quality objectives. Regional boards are already required to submit water quality objective implementation plans that list specific actions, time schedules, and surveillance measures to track progress.[22] Numeric nitrogen-related limits would provide growers with milestones to work towards while also helping the regional boards track progress on their water quality objectives. The Water Board must require, and make publicly available, field-level acreage data reported by growers through the Program so that the Water Board, the Expert Panel, and other researchers and stakeholders can analyze the data, recommend limits, and audit progress towards achieving water quality objectives.

Other countries have successfully adopted numeric limits on nitrogen pollution

Several regions around the world have successfully set science-backed limits on nitrogen fertilizers that have improved water quality. The attached literature review details how the European Union, EU Member Nations, and New Zealand established limits on fertilizer while not unreasonably burdening farmers. In Northern Italy, for example, after just two years of fertilizer application limits, surface water nitrate concentrations decreased by nearly 60 percent, and alluvial aquifer nitrate concentrations decreased by 23 percent.[23] Additionally, a 30-year study from Denmark shows the country reduced nitrogen loading into waterways by 30-50 percent with the help of fertilizer application limits[24] while maintaining their agricultural output.[25]

Conclusion

More than 25 years ago, the California Legislature required the Water Board to regulate pollution from agricultural lands to protect water quality for beneficial uses including drinking water, recreation, and agriculture.[26] That goal has not been realized, and instead communities and ecosystems continue to suffer. In 2012, California recognized the right of every person to safe, clean and accessible water for human consumption, but that Human Right to Water remains unprotected for many

Californians due to nitrate contamination. We urge the Water Board to develop numeric limits on nitrogen applications and discharges as soon as possible so that all Californians can have access to safe drinking water and healthy ecosystems.

Sincerely,

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Attachment:

Scientific Literature Review for Questions Posed to the Second Statewide Agricultural Expert Panel

July 31, 2025

Chief Deputy Director Karen Mogus
State Water Resources Control Board
1001 "I" Street, 24th Floor
Sacramento, CA 95812

RE: Scientific Literature Review for Questions Posed to the Upcoming Second Statewide Agricultural Expert Panel

Dear Chief Deputy Director Mogus and Members of the Expert Panel:

The undersigned organizations are excited to share a literature review for the Second Statewide Agricultural Expert Panel (Expert Panel or Panel) prepared by our agricultural soil scientist, Dr. Daniel Rath, PhD, and externally reviewed by several academics and nonprofit partners. As directed by the State Water Board (Board or Water Board), the Panel will analyze the information collected through the Irrigated Lands Regulatory Program (ILRP or Program) and recommend improvements to the Program to protect water quality, including setting nitrogen limits. The literature review follows the questions posed to the Panel by the Board and is intended to help Panel members understand the variables, data, and methodologies that contribute to successful nitrogen regulations around the world. Several regions around the world have set science-backed limits on nitrogen fertilizers that have improved surface and groundwater quality. Further, the literature shows that these limits do not unreasonably burden farmers. California has an opportunity to learn and lead from those models.

The European Union (EU) and New Zealand stand out as hallmarks of nitrogen regulation, and this literature review draws extensively on these two examples. For each question posed to the Expert Panel, the review describes how the European Union or EU Member Nation and New Zealand calculated limits, formulated methodologies, measured impacts, and considered exemptions. The literature review references the Findings that the Central Coast

Water Board made when developing their science-backed limits in Ag Order 4.0. Those Findings thoroughly analyzed nitrogen fertilizer data that the Central Coast Water Board collected from growers and concluded that the targets and limits are strongly supported by the latest science as well as global examples of nitrogen limits.

The literature shows that effective nitrogen regulations measure and reduce nitrogen surpluses from fields. Nitrogen surplus represents a rough estimate of the amount of nitrogen remaining in a field after harvest that has the potential of being lost to the environment through erosion or leaching. The Central Coast Regional Board's methodology of subtracting nitrogen removed (R) from nitrogen applied (A), or A-R, is one way of measuring nitrogen surpluses. An A/R ratio, on the other hand, represents an estimate of how efficient a specific crop is at using the applied nitrogen and does not provide any information about nitrogen losses into the environment. Ag Order 4.0's A-R limits and application limits seek to reduce nitrogen surpluses over time, making it a methodology that is more aligned with protecting water quality than a methodology that is solely calculated using A/R ratios. A/R ratios are a useful tool for estimating nitrogen use efficiency. But, A-R should be the primary metric used to inform limits because the regulation is designed to reduce nitrogen surpluses–thereby protecting water quality.

California's growing nitrogen problem tells a concerning story about the current structure of the ILRP. The Expert Panel can learn from the global examples of nitrogen regulation summarized in this literature review to make necessary improvements to the ILRP and track the Program's effort to protect water quality and the long-term sustainability of agriculture.

Sincerely,

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Natural Resources Defense Council

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Literature Review of Questions Assigned to the Expert Advisory Panel 2025

Prepared by Daniel Rath, Ph.D.

Methods

Using Google Scholar, we searched for terms including “agricultural nitrogen limits”, “agricultural fertilizer limits”, and “national fertilizer limits”. We also used a curated version of the ECOLEX policy databases compiled by authors of the Kanter et. al 2020 paper “Gaps and opportunities in nitrogen pollution policies around the world” and the Yang et. al 2022 paper “Policies to combat nitrogen pollution in South Asia: gaps and opportunities”, as well as conversations with the authors of both papers. We also considered nitrogen management strategies in place in the US, though limited examples of US regulations with numeric nitrogen application limits were found. Using these methods, we identified two policy examples for further expansion: the wider European Union (EU) Nitrates Directive and its varying levels of implementation in each member state, and the flat nitrogen application limit to pasture in New Zealand (NZ). Additional fertilizer limitation policies were identified in locations such as Sikkim, India and Sri Lanka, but were not considered in this context as these policies are more focused on eliminating nitrogen fertilizer than limiting its use. We then tailored search terms to identify the data, research, metrics, and methodologies behind the EU and NZ limits, and to find estimates of their impact on groundwater quality. To provide a comparison to a California- tailored program, we then reviewed the regulation and supporting information for the California Ag Order 4.0 program.

Acknowledgements

Thank you to the following academics for their time and effort in reviewing this summary for scientific accuracy: Dr. Iris Stewart-Frey, Dr. Jake Dialesandro, Dr Danielle Gelardi, and several anonymous reviewers. Thank you also to Natalie Herendeen, Nathaniel Kane, Tien Tran, Kjia Rivers, and Elias Rodriguez for their comments

Glossary

- **Nitrogen (N) Balance**:The difference between N inputs and N removed from agricultural systems. The A-R calculation in Ag Order 4.0 is one way to calculate this balance.
- **A-R Limit**: Also referred to as **nitrogen discharge limits**, these are limits on the total amount of nitrogen left over in the field throughout the year which has potential to be leached, calculated as nitrogen applied (A) minus nitrogen removed (R).
- **Application Limit:** Also referred to as **nitrogen application limits**, these are limits placed on the amount of nitrogen that can be applied to a particular field in a year.
- **Water Quality Limit**: The legal limit for the amount of nitrate-N that can be present in drinking water, currently set at 10 mg/L nitrate-N (40 mg/L nitrate) in the US, and 11.3 mg/l nitrate-N (50 mg/L nitrate) in the EU and New Zealand.

Table of Contents

Question 1: Is there enough data and scientific research to set crop-specific nitrogen-related limits (e.g., A/R, A-R, or other limits) that are protective of groundwater quality and support a long-term sustainable Irrigated Lands Regulatory Program? What metrics and methodology would be used for developing those limits and what would the limits be? What additional data should be collected and/or what additional research needs to be conducted to further support the development of nitrogen-related limits that are protective of groundwater quality and support a long-term sustainable Irrigated Lands Regulatory Program?

As this is a big question, it was divided it into 4 parts in order to survey the scientific literature:

Are there examples of data-driven crop-specific nitrogen limits globally?
What methodology and data were used to develop these limits?
Are these limits protective of groundwater quality?
What impact have these limits had on agricultural production?

Question 1A: Are there examples of data-driven crop-specific nitrogen-related limits globally?

European Union Nitrogen Limits

European Union (EU) limits on nitrogen application to agricultural land were first laid out by the Nitrates Directive in Dec 1991, spurred in part by the fact that close to 40% of groundwater monitoring points in some regions had concentrations over the legal limit of 50 mg/L nitrate (the EU limit of 50 mg/L nitrate, or 11.3 mg/L nitrate-N is comparable to the US limit of 10 mg/L nitrate-N). The directive was updated in 2003 and again in 2008, and the most recent evaluation in 2024 is being prepared.

The implementation of the EU-wide Nitrates Directive has 5 main parts:

1) Identifying polluted waters, or waters at risk of pollution (defined as surface or groundwater containing more than 11.3 mg/L nitrate-N)
2) Designating Nitrate Vulnerable Zones (NVZs - areas of land that drain into waters that are either polluted or at risk of pollution)
3) Establishing voluntary Codes of Good Agricultural Practices (Annex II) for all regions (including buffer strips, limiting when fertilizers can be applied, and instituting practices to prevent nitrate leaching)
4) Establishing compulsory action programs for farmers within NVZs (including the aforementioned good agricultural practices)
5) Limiting the application of nitrogen from manure - the highest amount of nitrogen from manure that can be applied annually is 170 kg N/ha (or ~156 lb N/acre.)

EU Member states are required to submit a report every 4 years containing nitrate concentrations in groundwater and surface waters, an assessment of program impact on water quality and agricultural practices, revisions of NVZ areas and action programmes, and estimates of future trends in water quality. While there is an EU-wide limit of 170 kg manure N/ha, the European Commission leaves it up to member countries to decide how those limits are enforced, and whether further action needs to be taken to protect water quality. This is due to the Commission's recognition that site-specific considerations (soil type, agricultural systems, etc) need to be taken into account when deciding what limits need to be set. Individual EU member states such as Denmark, the Netherlands and Germany that have more intensive agricultural areas and greater nitrogen pollution have set stricter regulations that include limits on all N application, including fertilizer N application.

The European Commission's Common Agricultural Policy (CAP) also requires that individual member countries provide payments to farmers that use sustainable farming practices to support climate, environment and animal welfare goals. These payments are often conditional (also known as cross-compliance) and country-specific, and are based on farmers meeting broad statutory management requirements in all regions, and on farmers achieving specific agricultural and environmental conditions in Nitrate Vulnerable Zones.

New Zealand Nitrogen Limits

New Zealand (NZ) limits on nitrogen application to agricultural land were put in place on 1 July 2021, in response to extensive nitrogen pollution of surface water, a pilot cap-and-trade program in one New Zealand watershed, and a related petition to the New Zealand government to ban nitrogen fertilizer application. New Zealand drinking water standards for nitrate-N are set at 11.3 mg/L nitrate-N, and surveys found an average national groundwater value of 5.05 +/- 6.87 mg/L nitrate-N with groundwater values of up to 16.9 mg/L nitrate-N in some hotspots. NZ fertilizer limits are meant to target heavy users of synthetic nitrogen fertilizer on grazed land and limit all nitrogen application on those grazed lands to 190 kg N/ha per year (169 lb N/acre per year). This does not include nitrogen applied to arable crop land, or biological nitrogen fertilizers.

Ag Order 4.0 Limits

Despite efforts to increase education and reporting of fertilizer applications, in a May 2018 staff report, the Central Coast Regional Board concluded that groundwater quality conditions in the Central Coast Region were experiencing worsening nitrate pollution, particularly in agricultural areas. An estimate of the average nitrogen waste discharge in 2017 was 209 pounds of nitrogen per acre per year, which worsened to approximately 340 pounds of nitrogen per acre per year, an "order of magnitude greater than the nitrogen waste discharge rate identified by the 2012 UC Davis Nitrate Report as being protective of water quality." (Attachment A, Page 148).

Using data collected and reported by regulated dischargers from 2014-2019 (which the Regional Board makes available online, here), groundwater quality tests, the 2012 UC Davis Nitrate Report, and research from UC Agriculture and Natural Resources and CA's Department of Food and Agriculture's Fertilizer Research and Education Program, the Central Coast

Regional Board proposed numeric limits on nitrogen application and nitrogen discharges. One of the equations used to calculate nitrogen discharge was :

$$A_{FER} + (C \times A_{COMP}) + (O \times A_{ORG}) + A_{IRR} - R = \text{Nitrogen Discharge}$$

while the equation used to estimate R (nitrogen removed) was:

$$R = R_{HARV} + R_{SEQ} + R_{SCAVENGE} + R_{TREAT} + R_{OTHER}$$

Details and definitions of the specific terms included in these equations are outlined in Ag Order 4.0 (page 24) and will not be outlined here.

The Central Coast Regional Board (CCRB) set the nitrogen application limits based on the 90th and 85th percentile of nitrogen applications according to Total Nitrogen Applied data submitted by growers from 2014-2019. The CCRB also set crop-specific limits for six crops with the most available data and research: lettuce, broccoli, spinach, cauliflower, celery and strawberry. Nitrogen discharge limits were set based on discharge levels that would protect water quality, initially starting with a target of 500 lb/acre, and ratcheting down to a limit of 50 lbs/acre/year with irrigation water or 150 lbs/acre/year without irrigation water after 29 years. Approx. 83% of Central Coast farms met the initial 500lb N/acre/yr discharge targets (Attachment A, Page 148).

To ease compliance and account for nutrient cycling dynamics, the Central Coast Regional Board offered discounts to the amount of nitrogen applied to farmers for using compost, planting cover crops, and adding high carbon amendments. Based on implementation of practices that have been shown to reduce nitrogen pollution, these discounts reduced the amount of nitrogen included as nitrogen applied (ie. compost, organic fertilizers) or increased the nitrogen removed (ie. cover crops) . For compost, based on the C:N ratio, only 5-10% of the nitrogen is plant available, therefore the application rate can be multiplied by on average 0.05 (C:N>11) or 0.10 (C:N<11), effectively 'discounting' the nitrogen applied from compost. (Attachment A, page 151). The compost discount factors were informed by the compost nitrogen mineralization rates in Gravuer et. al (2016) as part of Governor Newsom's Healthy Soils Initiative (Attachment A, Pages 151-152). The cover crop discount factors were informed by field trials conducted in the Central Coast through the UC Agriculture and Natural Resources Department (Attachment A, Pages 153-154). Current work by Dr. Eric Brennan and Dr. Daniel Geisseler aims to improve our understanding of cover crop nitrogen uptake and subsequent residue decomposition and whether the discount factor criteria (found in Q7) could be expanded to include fall-terminated cover crops, which in the Central Coast has the potential to avoid delaying spring planting.

An additional method to reduce costs with the Ag Order is a third-party alternative compliance pathway for groundwater dischargers in high priority watersheds. Farms that were members in good standing of third party groundwater coalitions were not subjected to immediate enforcement of the fertilizer nitrogen discharge limits and were allowed more time to achieve nitrogen discharge and application targets relative to non-participating farms. Only if a particular farm failed to meet the discharge targets for a three-year running average, or application targets for a two-year running average would they become ineligible to participate in a third party coalition. Ineligibility for participation in a third party coalition would only occur after a 90 day advanced notice period, and after Water Board staff established that noncompliance was not due to unforeseen or uncontrollable circumstances (Ag Order 4.0, pg 32).

Question 1B: What methodology and data were used to develop these nitrogen-related limits?

Nitrogen Balance Values Worldwide

Remanded Ag Order 4.0 Limit - 50 lb N/acre/yr
EU-wide Recommended Limit- 44-71 lb N/acre/yr
German Limit- 45 lb N/acre/year
Proposed Chinese Limit- 35-89 lb N/acre

EU Methodology

While EU documents are not clear on the specific methodology used to arrive at the 170 kg N/ha manure limit, there is some evidence that it was based on both average manure N application in member states (between 100 and 304 kg N/ha) in the 1990s, as well as on manure application limits passed by the Dutch government in 1987.

EU Country-Specific Methodology

Nitrogen fertilizer limits are calculated with varying levels of complexity in almost every EU member state. A partial overview and list of methods can be found here.

Limits in Denmark are set according to a protocol made by a government-appointed board with members from the Ministries of Agriculture and Environment, the universities, and agricultural NGOs. N rate limits are set at the optimum economic rates as determined by N rate-response trials and the price of nitrogen fertilizer, and then these economic rates are modified with multiple corrections for protein content of the crop, soil type, manure and cover crop residue, and forecasts of the amount of available N for that region.

In Germany, N fertilizer limits (Annex 4) are determined by taking crop-specific nitrogen requirements, and subtracting estimated N that will be provided by residual soil nitrogen, predicted soil N mineralization, N supply from the breakdown of organic fertilizers applied in previous year, and N supply from cover crop and previous crop residues. The final value is used as the limit for N application for a particular year. The values for these calculations are based on baseline data from a specific region of Germany (Bavaria). Germany has also stated their target of reaching a countrywide 5-year average nitrogen surplus of 70 kg/ha (~65 lb/acre) by 2032 to protect water quality, a value based on the report of the 2015 EU Expert Panel on Nitrogen Use Efficiency.

NZ Methodology

Since the New Zealand limit is a flat limit that does not change annually, it does not involve detailed calculations like Denmark. Limits were based on research that showed that reducing nitrogen application on grazed land below 200 kg N/ha would be beneficial for water quality. The specific number of 190 kg N/ha comes from estimates of maximum return to nitrogen for NZ grasslands.

Ag Order 4.0 Methodology

The Central Coast Regional Board set fertilizer application limits at the 90th and 85th percentile of fertilizer applications reported by lettuce, broccoli, spinach, cauliflower, celery, and strawberry growers from 2014-2019. For all other crops, the initial fertilizer application limit was set at 500 pounds of nitrogen per acre per crop, to be revisited based on further data reporting (Attachment A, pg 149, 150). It was stated in Attachment A to Ag Order 4.0 that over 98 percent of all crops on the Central Coast met the initial 500 lb N/acre/crop application limit. The stated goal was to allow the Central Coast to mitigate nitrogen runoff by the top overappliers- in essence, tackling outliers first. As the Central Coast noted in Attachment A of their Ag Order 4.0, "The ESJ Order approach involves making comparisons among the population of Dischargers to determine "outliers." The crop-specific application limits established in this Order follow that approach." (Attachment A ,Page 145, Paragraph 23).

Ag Order 4.0 also set a final nitrogen discharge limit of 50 lb N/acre by 2051. This level was set with the goal of allowing groundwater aquifers to achieve the safe drinking water threshold of 10 mg/L of nitrate-N concentration by 2051 (Attachment A ,Pages 149-150, Paragraphs 29-32). Calculation of this limit was based on the 2012 UC Davis Nitrate Report:

1) The concentration of nitrogen (as NO3-N) in an acre-foot of water (325,851 gallons) will increase from 0 to 10 mg/L, the nitrate MCL, when approximately 27.2 pounds of nitrogen is added.
2) The 2012 UC Davis Nitrate Report determined that nitrogen discharge in excess of 31 lb N/acre/yr would have the potential to cause exceedances of the MCL. This value accounts for the 27.2 value discussed above, and also includes an additional 4.5 pounds of nitrogen/acre/yr to account for losses due to potential denitrification in the deep vadose zone or in shallow groundwater, arriving at approximately 31 lb N/acre/yr.
3) The typical groundwater recharge rate identified in the 2012 UC Davis Nitrate Report study area was approximately 1 acre-foot of water per acre per year. Based on information submitted in the TNA reports, and accounting for additional recharge due to rainfall, the typical groundwater percolation rate in irrigated agricultural areas in the Central Coast is likely closer to 1.66 acre-feet per acre per year. This allows for the loading limit to be increased: 27.2 x 1.66 + 4.5 = 49.7, which rounds to 50 pounds of nitrogen per acre per year.

To provide flexibility in achieving the nitrogen discharge limits, the Central Coast Regional Board provided growers with two different ways to calculate nitrogen use based on the different ways growers manage nutrients on their farms. This included whether a grower applies compost, organic fertilizers, high carbon amendments, and/or irrigation water. The Order provided two options for cover crop N credits to ease compliance with the nitrogen discharge limits - either a flat 30 lb N/acre/yr removal credit, or credit equal to 97% of the N content of a non-legume cover crop that meet certain criteria (Page 154, Paragraph 50, Attachment A; Q7). The Regional Board also noted that both the incentives and numeric limits would be re-evaluated and updated to account for new research, the results of new monitoring and reporting data, additional nitrogen data submitted by growers, and an expert panel's evaluation and recommendations prior to limit enforcement coming into effect in 2032. (Attachment A, Page 89, Paragraph f).

Question 1C: Are these limits protective of groundwater quality?

EU Results

There are two metrics that have been used to estimate whether the EU's Nitrate Directive has had a positive effect - estimates of N surplus and leaching calculated from farmer reporting data, and actual water quality measurements.

Surplus and Leaching Calculations

The EU experienced a sharp increase in nitrogen surplus from 1960-2000, after which nitrogen surpluses in most countries began to decline. A 2014 estimate showed that nitrate leaching had been reduced across the entire EU by 16% between 2001-2008 due to the Nitrate Directive, but that the leaching reduction in intensive agricultural areas was much larger - a 60% reduction in nitrate leaching in specific areas in the Netherlands and a 48% reduction in Denmark. By 2015, the Netherlands had seen reductions of over 50% in their countrywide nitrogen surplus, most of which came in the first ten years after limits were introduced. A more recent 2019 estimate showed that the agricultural N surplus had been reduced by 33% across the entire EU, and by 50% in the Danube region after the passage of the Nitrates Directive.

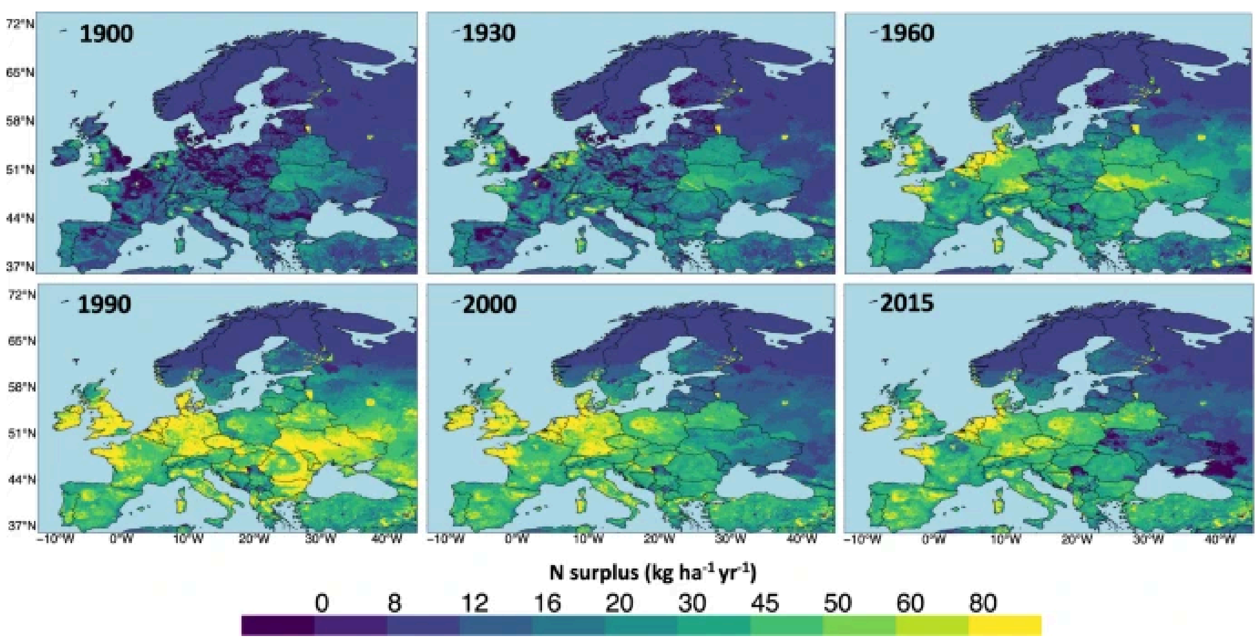

Fig. 1. Snapshots of N surplus ($kg\ ha^{-1}$ of grid area yr^{-1}) across Europe between 1900-2015. Taken from Batool et. al 2022

Water Quality Measurements

The impact of the Nitrates Directive differs depending whether we consider surface water or groundwater. In Northern Italy, stream nitrate levels were found to decrease by 59% within a year of implementing nitrogen application limits. In Denmark, stream nitrate loads have fallen by between 30 and 50% between 1990-2018 by one estimate, and total nitrogen load to coastal waters has fallen by 45% since 1990 by another estimate. This has resulted in a decreased area of water under anoxic conditions off the Danish coast, analogous to the Gulf of Mexico's "Dead Zone" in the US.

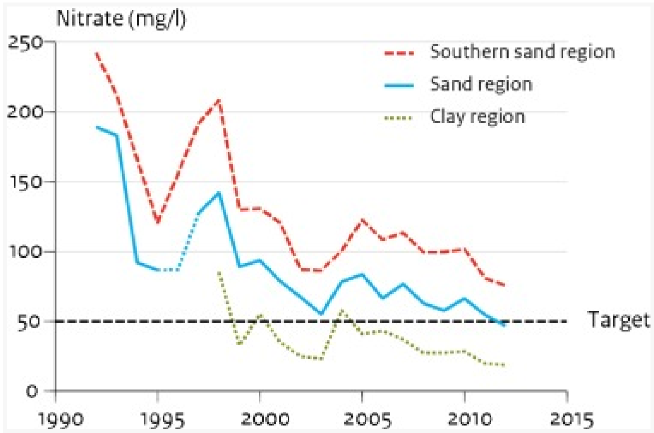

Fig. 2. Nitrate levels in Danish groundwater between 1990 and 2015. For context, 250 mg/L of nitrate is 56 mg/l nitrate-N, 5.6x the current US limit for drinking water. Taken from Petersen et. al 2021.

Impacts of the Nitrate Directive on groundwater are more inconsistent, particularly when looking at the entire EU, potentially due to aquifer properties or differing lag times in nitrate leaching to groundwater. Groundwater nitrate concentrations averaged across the entire EU have not shown a significant change since 1990. However, a 2017 report showed a clear improving trend in groundwater nitrate concentrations in Denmark starting in the 1980s, and between 2004 and 2007, nitrate concentrations at 66% of groundwater monitoring points were stable or improving, while surface water nitrate concentrations remained stable or fell at 70% of monitored sites. For shallow groundwater, nitrate levels in some areas (particularly sandy soils in the Netherlands) have been cut in half from 1997-2010 (Fig. 2), though the same benefits are not seen everywhere in the country. Data from 2008-2023 collected by the German Environmental Affairs Office has shown a small decrease in the number of sampling sites that exceed the limit for groundwater, but concluded that more efforts are still needed to reduce agricultural N input.

NZ Results

NZ's nitrate limit regulation was passed in 2023 so there is limited data available, but one estimate of nitrogen leaching showed an average decrease of 15% (-6 kg N/ha) in one region (Canterbury) and 32% (-22kg N/ha) in another (Southland).

Ag Order 4.0 Results

Ag Order 4.0 was remanded before data could be collected on the results of their fertilizer application caps and nitrogen discharge limits. However, with data collected from 2021-2023, the Central Coast Regional Board reported that 28% of on-farm domestic wells sampled and 29% of irrigation wells sampled had mean nitrate-N concentrations that exceeded the safe drinking water threshold of 10 mg/L nitrate-N.

Question 1D: What impact have these limits had on agricultural production?

EU-Wide Impacts

While no studies were located that expressly considered the impact of the Nitrate Directive against a counterfactual (i.e what would have happened to agricultural production had the Directive not been implemented), overall EU agricultural production has continued to increase since 1991. Between 2009 and 2021, there was an upward trend in the output volume of the EU's agricultural industry, declines in 2022 and 2023, and an estimated upturn in 2024. The output of the EU's agricultural industry was an estimated 6.8% higher in 2024 than in 2009.

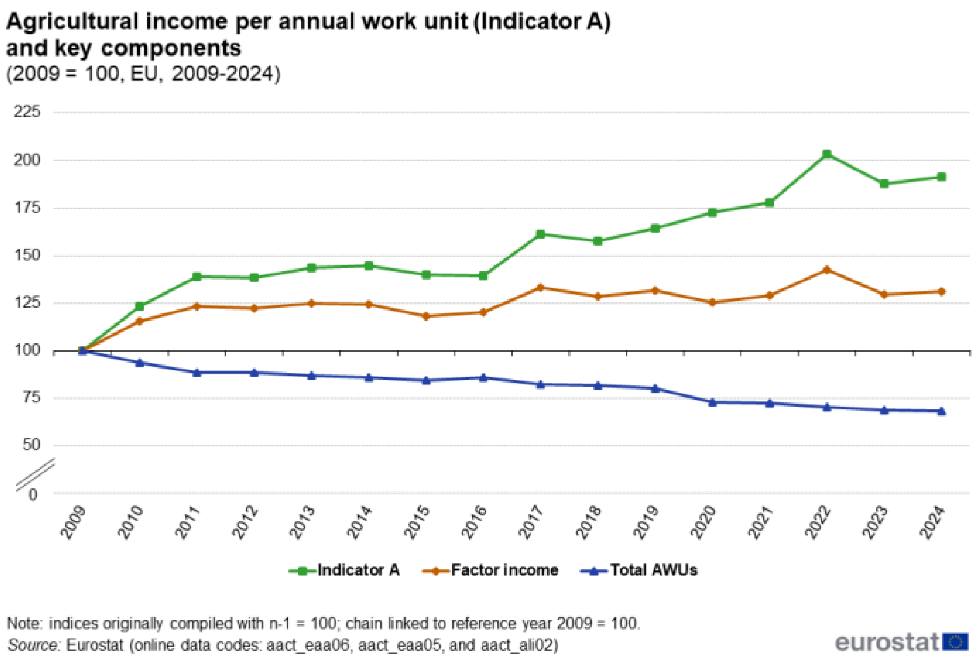

Fig. 3. EU agricultural income per annual work unit (AWU - work performed by one full-time person in agriculture in one year) 2009-2024. While the total number of agricultural workers has declined by around 2.5% per year since 2009, income per person has increased by 91.6% since 2009 (Indicator A). Taken from Eurostat.

It is worth noting that the locations with the most intensive agricultural production and most stringent N regulations (Germany, Netherlands, Denmark, Belgium) were the only regions that saw both growth in agricultural output and a decrease in intermediate consumption (i.e. total cost of inputs) between 2009 and 2024. These changes were attributed to both increases in resource efficiency, and unrelated changes to the agricultural industries in those regions.

With regards to farm income, EU farm income per worker was 91.6% higher in 2021 than in 2013, far outpacing inflation during the same period (9.4%). The upward trend in farm income per worker from 2013 to 2021 was attributed to a faster growth of the production value than the growth of costs, leading to a higher total income per farm; and a decrease in farm workers.

EU Country-Specific Impacts

Estimates of the impact of nitrogen regulations on Danish farmers differed between the period 1997-2016. Before 1997 and after 2016, N fertilizer quotas for crops were based on economically optimal N rates taking fertilizer and crop prices into account, with the goal that the quota system should not result in loss of yield or reduced crop quality. On average, this meant that the manure N limits did not result in losses of yield and quality. Between 1997-2016 however, N quotas were set 10-15% lower than the optimal economic rates, which led to an estimated loss of 0.06-0.24 metric tonnes/acre/year in wheat yields. Estimated income losses for farms ranged from $25/acre/year- $83/acre/year.

An estimate of the compliance costs of nitrate regulations on German livestock and pig farms showed that compliance costs were highly heterogenous, with 47.3% of pig farms and 38.4% of dairy farms not facing any costs. For those farms that did pay compliance costs, they ranged from $0-3.10 per pig, and $0-0.97 per kg of milk. Compared to the costs of feeding and livestock replacements, compliance costs with fertilizer regulations were small.

A comparison of N regulations in France and other EU countries outlined the differences in impact between EU voluntary and regulatory approaches on farmers. Policies in the north of Europe have focused action on regulatory compliance with N balances and limits, while promoting structural changes through cross-compliance payments. Responses to these policies have been multi-pronged: reduced herd sizes (esp. the Netherlands), increased farm sizes and increased specialization. These structural shifts have aimed to increase added value per unit of nitrogen excreted. By contrast, until 2011, France based its manure policy on controlling and supporting its livestock farming structures, without corresponding regulatory control of nutrient surpluses. The French approach pre-2011 appears to have led to an increased amount of complex and non-restrictive regulations that did not produce environmental results.

NZ Impacts

While the recent nature of the NZ farm regulations has not allowed for extensive analysis, one 2023 estimate is that gross farm incomes had increased by approximately 13% from 2020-2023 (NZ regulation was passed in 2021), but that on-farm inflation had also increased by 27% in the same time period. Farms also saw a 42% increase in operating expenses, attributed to higher feed costs (since less fertilizer and grassland productivity requires more feed import), and increased fertilizer costs. An analysis of the NZ pilot cap-and-trade program also showed that the trading system has provided useful flexibility for landowners and has decreased the cost of achieving the community's environmental goals, albeit resulting in increased compliance costs for farmers.

Ag Order 4.0 Impacts

As Ag Order 4.0 was remanded two years after being implemented in 2021, there is limited information on its impact on agricultural productivity separate from the overall ILRP program.

Question 2: Based on the data and scientific research that is currently available, what series of increasingly protective interim nitrogen-related limits can be set now to ensure that all growers make progress towards nitrogen-related limits that are protective of groundwater quality and support a long-term sustainable Irrigated Lands Regulatory Program?

In reviewing the literature, we searched for examples of interim limits and timelines globally. This included interim limits proposed in Ag Order 4.0, limits set EU-wide and EU member state limits.

EU-Wide Interim Limits and Timeline

- Initial legislation: **1991**
- Time between legislation and enforcement of Interim Limits: **7 years**
- Time between interim Limits and current limits: **4 years**
- Time between current limits and N discharges protective of water quality: **28 years**

In the EU, flat limits on manure application of 210 kg N / ha (~187 lb N/ acre) first came into effect 7 years after the original Nitrate Directive was passed in 1998. Those limits then ratcheted down to 170 kg N/ha (152 lb N/acre, the current limit) four years later, or 11 years after the Nitrate Directive was first passed (2002). (Table 1). Member countries had two years after the Directive to establish monitoring programs, designate zones with excessive nitrate pollution, and outline voluntary programs to reduce nitrogen application. After this, member countries had an additional two years to establish mandatory action plans, including "limitation of the land application of fertilizers" based on a balance between crop nitrogen needs and nitrogen supply existing in the soil (**91/676/EEC, Annex III**). These timelines differ depending on the country. The current EU goal is to reduce nitrogen losses by ~50% by 2030 compared to 1990 levels.

Requirement	Relevant Directive Article	Stipulated Completion Date[13]
Transposition into National Law	12	20.12.1993
Monitoring	5(6) or 6	20.12.1993
Designation of Vulnerable Zones	3	20.12.1993
Establishment of Code of Good Agricultural Practice	4	20.12.1993
Establishment of first four year Action Programme	5	20.12.1995
Submission of Summary Report to Commission	10	20.6.1996
Completion of the Review of Designations	3	21.12.1997
Start of the year during which maximum of 210 kg N ha may be applied	5	20.12.1998
Completion of first Action Programme	5	20.12.1999
Start of the year during which maximum of 170 kg N ha may be applied	5	20.12.2002
Completion of second Action Programme	5	21.12.2003

Table 1. Taken from the 1997 report on "The Implementation of Council Directive 91/676/EEC concerning the Protection of Waters against Pollution caused by Nitrates from Agricultural Sources"

Danish Interim Limits and Timeline:

- Initial legislation: **1991**
- Time between legislation and enforcement of initial limits: **3 years**
- Time before first limit revision: **3 years**
- Time before revised limits were implemented: **2 years**
- Time before second limit review: **7 years**

Danish policy to reduce the amount of phosphorus and nitrogen runoff dates back to 1985 focusing on increasing the use of catch crops (a European term that refers to cover crops grown between main crops to capture nitrogen that would be lost by leaching or runoff) and improved manure storage. By 1990 it was clear that this approach alone would not meet N leaching reduction targets, so the first limits on N application at economically optimum levels were proposed in 1991 as part of Nitrate Directive compliance, with stepwise implementation of N limits from 1994 onwards. A proposal to further limit N application to 90% of economically optimum fertilizer levels was put forward in 1997, and implemented in 1999. This N limit of 90% of economically optimum levels was repealed in 2016, and replaced with more location-specific limits and greater requirements for catch crops. The Danish target is to reduce nitrogen surplus to 42 kilotonnes N/year by 2021 with a further reduction to 37 kilotonnes N/year by 2027.

New Zealand Limits and Timeline:

- Initial legislation: **2020**
- Time between legislation and enforcement of initial limits: **2 years**

New Zealand N regulations were introduced in September 2020, but did not take effect until July 1, 2022. The 190 kg/ha/year limit did not have any interim limits and has not yet been revised.

Remanded California Ag Order 4.0 Interim Limits and Timeline

- Initial order: **2021**
- Time between order and initial application limits/discharge targets: **2 years**
- Time between initial application limits/targets and second round of limits/targets: **2 years**
- Time between second round of limits and final limits protective of water quality: **25 years**

The Central Coast's Regional Board issued Ag Order 4.0 in 2021, and growers were given two years (end of 2023) to comply with the first set of nitrogen application or discharge targets depending on whether they were part of a third party coalition (Q1A). For flat application limits, these were initially set at the 90th percentile of current application by crop and ratcheted down to the 85th percentile in 2025 (4 years). For those growers applying irrigation water, nitrogen discharge targets were initially set at 500 lb N/acre/yr to take effect in 2023 (2 years), and enforceable nitrogen discharge limits were set at 300 lb N/acre/yr, to take effect in 2027 (6 years). Growers not using irrigation water had other targets and limits. Nitrogen discharge limits were then to be ratcheted down on a sliding timescale to a final limit of 50 lb N/acre/yr nitrogen discharge for all growers by 2051 (30 years, Tables C.1-2 and C.1-3). Compliance with the Ag Order was also phased based on which Groundwater Phase Area (1-3) farmers were in, with Phase 1 areas being the areas where water quality is most threatened.

Question 3: Are there any scientific or technical considerations or advances related to the factors discussed in the First Agricultural Expert Panel's 2014 Report that the State Water Board should take into account in future policy decisions regarding implementation issues or the direct enforceability of the nitrogen-related limits described above?

The key factors of a regulatory program discussed in the 2014 EAP Report (page iv) include:

1) The need for coalitions to mediate between farmers and regional boards
2) Use of the A/R metric as the primary metric to determine progress on controlling N runoff
3) The need for strong, comprehensive and sustained outreach programs
4) The need to create and implement region and crop-specific nitrogen plans
5) Reporting of key values by farms to coalitions
6) Trend monitoring of groundwater nitrate concentrations
7) Research on how to increase yield and reduce A/R values
8) The use of multi-year values to estimate progress as opposed to single-year values

We evaluated literature pertaining to factors 2, 4, and 6 using global examples, as well as literature pertaining to the benefits of improved soil health.

Use of A/R as the primary metric to determine progress

The 2014 report's recommendation of the A/R metric was partially based on the idea that detailed nitrogen cycle computations were too difficult and expensive to accurately estimate.[1] However, Mclellan et. al 2018 showed that measured N balances (calculated solely as total inorganic N input minus crop-specific nitrogen removed at harvest, and the principle on which A-R estimates are based) had a strong relationship with environmental N losses and served as a "robust measure of nitrogen losses that is simple to calculate, easily understood, and based on readily available farm data." These findings have led to US technical instruments such as the Environmental Defense Fund's nitrogen balance model. Nitrogen balance calculations are a cornerstone of EU regulatory programs in several countries. An additional point is that A/R ratios are unitless and cannot provide quantitative estimates of how much nitrogen is potentially being lost to the environment on their own, a fact that was reflected in the State Water Board's 2018 Order requiring collection of data on A-R alongside A/R, and the 2021 Ag Order 4.0's use of A-R as the primary metric for determining progress.

A/R estimates do provide important information on the efficiency of agricultural nitrogen use that can supplement nitrogen balance estimates. The 2015 EU Expert Panel on Nitrogen Use Efficiency proposed the idea of a safe operating space for crop production that was defined by a minimum acceptable level of productivity (to meet food needs), a maximum acceptable level of

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[1] Pg 24 of the 2014 EAP report - "Detailed nitrogen cycle computations *[i.e. nitrogen balances]* for individual fields, for a growing season, will be fraught with error and unnecessary expense. The difficulties for experts are tremendous, and are unrealistic expectations for farmers. Therefore, the Panel does not recommend that such computations and associated data collection be required as part of the regulatory process"

N balance (to minimize N pollution), and an acceptable range of nitrogen use efficiency (NUE; the ratio of N inputs to outputs). Another example is China's "Two Zeros" program which aimed to achieve zero growth in both fertilizer and pesticide use by 2020. Specific targets for this policy were to increase NUE to above 40% by 2020, while also trying to meet N surplus benchmarks of between 40-100 kg N/ha depending on the crop (35-89 lb N/acre).

Development of Site and Crop-specific plans

The development of site and crop-specific plans is a key factor in the EU regulatory system. The implementation of the EU Nitrate Directive is left up to individual countries, with the only EU-wide requirement being the 170 kg N/ha limit on manure application. The current iteration of Danish nitrogen regulations has moved away from a country-wide nitrogen quota towards more site and crop-specific N quotas, which take into account the nitrogen removed in yield, protein content of the crop, soil type, manure and cover crop residue, and forecasts of the amount of available N for that region and year. Ag Order 4.0 included crop-specific nitrogen application limits for the top 6 crops by acreage on the California Central Coast, and standard application limits for all other crops (Table C.1-2).

Trend Monitoring

Monitoring nitrate trends in surface and groundwater over time is a key indicator of progress for the EU regulatory program. Member states have established monitoring programmes and report to the European Commission at intervals on the results of these monitoring programmes (Example for Malta). These nitrate trends are then used to evaluate the effectiveness of country-specific programs, and to determine whether some member states' request for exceptions to the nitrogen application limit can be scientifically justified.

Soil Health Improvements

In the last ten years, there has been an increased focus on the role of improved soil health in reducing nutrient inputs and leaching, improving biodiversity, and reducing risk in agricultural systems. One of the main paradigm shifts is the increased importance of soil organic matter in providing nitrogen to crops. Plant N availability within a growing season may be more closely related to the rate of mineralization and cycling of nitrogen than to the size of soluble N pools in the soil. The release of nitrogen from organic matter can provide a substantial amount (between 64-89% of N needs by one estimate) of bioavailable nitrogen, which can, in soils with sufficient organic matter and an active microbial community, decrease the need for soluble nitrogen application via fertilizer. Increased soil health can also improve soil biodiversity, which can in turn increase rates of nitrogen mineralization and increase the amount of nitrogen stored in organic forms that are less susceptible to leaching. Increasing the abundance of specific soil microbial groups, such as mycorrhizal fungi, can increase the amount of soil scavenged for nitrogen and potentially reduce soluble N pools susceptible to leaching. The inclusion of nitrogen mineralization in the calculation of A-R is one area that shows great promise for more accurate calculations.

Question 4: Is A-R a scientifically appropriate metric to evaluate and quantify nitrogen discharges to groundwater (either on its own or used in conjunction with A/R)? Are there any other methods or metrics that could help quantify nitrogen discharges?

To evaluate this question, we searched for examples of regulatory schemes and research using A-R to evaluate leaching to groundwater, as well as alternate uses of the A-R metric.

Is A-R a scientifically appropriate metric to evaluate N discharges to groundwater?

Evidence suggests that A-R estimates calculated from field reported application and yield data are appropriate for evaluating N discharges to groundwater. A-R estimates have already been used in the literature to evaluate the potential for nitrogen loading to groundwater in California - mass balance estimates produced by a detailed A-R equation were found to correspond to estimates of nitrogen loading in Central Valley aquifers. Nitrogen balances have also been used to evaluate the potential N loss impacts of different cover crop types in California. Nitrogen balances have "proved to be a useful predictive indicator of the risks of N–loss to groundwater from agricultural nonpoint sources" in Spain and have identified high nitrate risk areas in Poland.

Overall, these A-R estimates have been shown to have a strong relationship with environmental N losses. As outlined in the 2015 EU Expert Panel on Nitrogen Use Efficiency, nitrogen balance estimates can be supplemented with nitrogen use efficiency data to outline a safe operating space for N fertilization, but maximum surplus value (A-R) is the value most directly related to environmental pollution, and is a proxy for potential N losses to the environment.

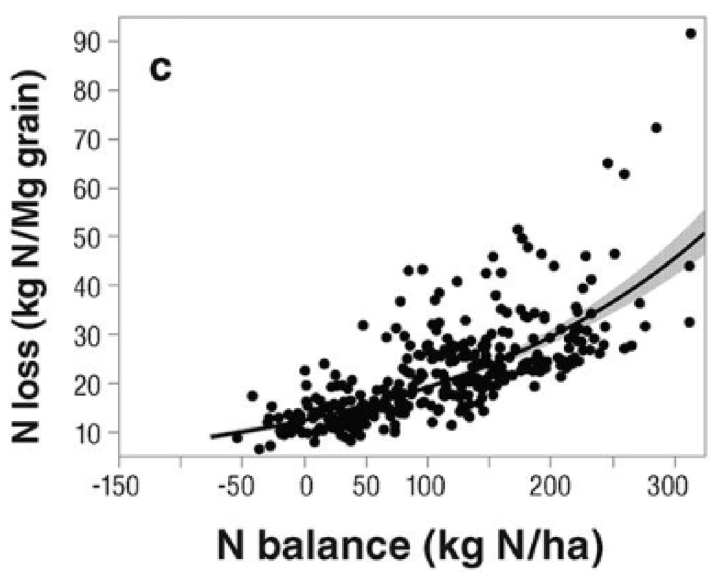

Fig. 5 Yield-scaled N loss (N loss per approx 1 ton of grain) vs N balance. Taken from Mclellan et. al 2018

One of the specific goals of the A/R ratio is to represent how efficient a specific crop is at using the nitrogen it is given. Comparing the A/R ratios of different crops can indicate which of them are more efficient at using applied nitrogen to produce harvestable yield (better nitrogen use efficiency), with the crops that have A/R ratios closer to 1 being more efficient in their nitrogen use. However, the A/R ratio is unitless and does not actually provide a quantitative estimate of nitrogen loss. For a quantitative estimate, we require A-R, which is an estimate of the amount of nitrogen remaining in the field after harvest that has the potential to be leached. By combining A-R estimates and acreage information, we can get an idea of the potential amount of nitrogen that can be leached to groundwater in a specific area.

One limitation of A-R calculations is that they may not consider the amount of nitrogen provided from mineralization of soil organic matter. This can lead to both an overestimation of the amount of nitrogen that needs to be applied (since the soil is supplying nitrogen) and an underestimation of the amount of nitrogen in a field with the potential to leach to groundwater. This issue has been addressed in several ways in EU regulations. In Germany (Table 11), static estimates of N supply from soil organic matter are grouped into different categories - grasslands, peatlands, and forage grasses, and range from 10-80 kg N/ha. In Denmark (page 23), a nitrogen mineralization "forecast" is prepared each year for three soil type categories indicating the difference in nitrogen mineralization between the current spring and an 11-year reference period. The sample data for the Danish reference period comes from a combination of undisturbed fields, fields that do not receive manure, and winter-sown fields. Similar work on estimating regional N mineralization has already been done in California, and has shown that N mineralization predictions should account for soil texture, organic matter content, and C:N ratio.

Are there any other methods or metrics that could help quantity nitrogen discharges?

Löw et. al 2021 compared several different versions of nitrogen balances that were in use in Germany - SoilB, FertP and FarmB. SoilB, or soil balance is a net soil surface balance related to N in applied fertilizer, calculated as Napplied-Nremoved/Acreage with a limit of 50 kg/N/ha. Farm B (farm balance) is a newer method of calculating nitrogen balances meant to overcome issues with accuracy of self-reported data, and is considered a more integrative and transparent indicator of nutrient management. Farm B nutrient accounting is based on invoices, delivery notes, and product declarations for nutrients (e.g. mineral fertilizers, feedstuffs) or standard values (e.g. nutrient content of animal products, excretion factors). All products containing N or phosphates that enter the farm from external sources are considered 'inputs' and all products containing N and phosphates that leave the farm are considered 'outputs'. The actual gross farm-gate balance limit is an N surplus less than 175 kg N/ha averaged over 3 years.

Finally, FertP is a mandatory, site-specific tool based on crop-specific nutrient demand values and nutrient availability from soil and previous crops. It is calculated using the nutrient supply from soil, soil type, previous organic fertilization, estimated yield and plant-available N in spring and establishes a farm-specific maximum total N application. The underlying concept in FertP is an implicit limit of zero, as fertilizer inputs shall meet, but not exceed the plant needs.

A comparison of all three methods showed that all were effective in reducing nitrogen application, but they also have different impacts on production, with FarmB being potentially less onerous for data submission, as well as the least restrictive.

Question 6: The 2021 Central Coast Ag Order established nitrogen application limits (AFER) based on percentiles of known grower practices in the region and considered the California Fertilization Guidelines on the California Department of Food and Agriculture website: California Crop Fertilization Guidelines. This approach was remanded in the Central Coast Ag Petition Order. Is using AFER in this manner an appropriate metric for interim limits to protect groundwater? If yes, what should those limits be?

Ag Order 4.0 AFER Limits

The reasoning behind Ag Order 4.0's establishment of nitrogen application limits is outlined in Order No. R3-2021-0040, Attachment A, p143. In short, data collected from 2014-2019 showed that fertilizer nitrogen application rates had not changed significantly in response to reporting requirements alone. The 2016 California Nitrogen Assessment also established that over-application of synthetic fertilizer nitrogen is one of the primary drivers of groundwater nitrate contamination. To comply with the approach taken in the 2018 ESJ Order to consider nitrogen application outliers, the order established fertilizer application targets and limits based on the 90th and 85th percentile of nitrogen applied between 2014-2019 specifically to target nitrogen overapplication. These fertilizer application limits were meant to be used in tandem with nitrogen discharge limits to both limit overapplication and ensure discharge levels that were protective of water quality.

Ag Order 4.0 also established crop-specific application targets and limits for the six most commonly reported crops on the Central Coast, with the reasoning that these crops had the most data points each year and had been studied by researchers more than other crops in the region. All other crops were given an initial nitrogen application limit of 500 lb N/acre/year. These limits were applied separately to multiple crops grown on one field per year (i.e. separate fertilizer application limits for spring lettuce and fall lettuce) (Ag Order 4.0, Table C.1-2, caption). The fertilizer application targets and limits for these crops were evaluated as being near or greater than the application recommendations from the California Crop Fertilization Guidelines.

EU and NZ AFER Limits

As outlined in Q1A, manure nitrogen application limits of 170 kg/ha are the only limit that applies to all EU member states - this limit is one of the defining features of the Nitrate Directive, and is intended to improve groundwater quality by reducing overapplication of nitrogen. This application limit is then supplemented by additional limits in member states. As outlined in Q1B, several of these member states use an approach where N balance calculations of nitrogen applied, residual soil nitrogen, nitrogen removed via yield, etc. are used to calculate the maximum amount of nitrogen that can be applied in a particular year.

New Zealand's nitrogen application limits of 190 kg N /ha/yr from all sources are also the defining feature of its nitrogen regulation, and are intended to be protective of groundwater quality.

Question 7A: The 2021 Central Coast Ag Order included discount factors to A (compost [ACOMP], organic fertilizer [AORG]), additional components of R (RSCAVENGE, RTREAT, and ROTHER), and excluding nitrogen in irrigation water from the calculation of total nitrogen applied in compliance pathways. Are the discount factors and additional components of R included in the 2021 Central Coast Ag Order's compliance pathways appropriate measurements to include in A and R calculations when measuring the potential to discharge nitrogen to groundwater and, if so, are these applicable to use statewide?

EU Use of Discount Factors

The use of discount factors and credits to represent the fact that not all nitrogen applied in organic forms is immediately available (Q3), and that nitrogen can be retained or removed in several different ways has been used widely in EU regulation. EU methods for calculating nitrogen available to crops can use between 3 and 16 variables depending on the country, but some of the most common factors include the nitrogen mineralized from manure, the nitrogen mineralized from crop residues, the nitrogen mineralized from soil organic matter, and the nitrogen present in the soil at the start of the season.

Examples of nitrogen credits under the German fertilizer regulation (*Düngeverordnung*) include a spring nitrogen credit of up to 60 kg N/ha for non-legume cover crops, reduced to 20–40 kg N/ha for cover crop mixtures containing 30–75% legumes, and no credit for mixtures with more than 75% legumes, due to their high nitrogen-fixing capacity. Additionally, nitrogen already present in the soil, estimated through soil tests or regional values, is subtracted from the crop's fertilizer allowance. These values represent the maximum mineral nitrogen a grower is allowed to apply, with both cover crop composition and soil N levels reducing the need for spring fertilization. Nitrogen 'credits' in the German system work differently than in the U.S., with 'credits' for Germany meaning how much nitrogen is allowed for spring application, rather than how much nitrogen is fixed. Additionally, Denmark, the Flemish Region, and the Netherlands use discount factors to calculate the fertilizer equivalency of various organic amendments. Values for these discount factors range from 0.7 for cattle slurry to 0.1 for compost.

Ag Order 4.0 Use of Discount Factors

Ag Order 4.0 used discount factors for both compost and organic fertilizer in their calculation of N discharges (Ag Order 4.0, pg 24). Both discount factors are meant to represent the amount of nitrogen mineralized from these organic amendments after application. The compost discount factor ranges from 2-15% depending on the C:N ratio of the compost, while the organic fertilizer discount differs more widely depending on the C:N ratio of the amendment. (Attachment A, Page 152-153).

Ag Order 4.0 also included an innovation in the calculation of nitrogen removed: the use of two different methods to calculate N scavenging from non-legume winter cover crops. The first option is a flat 30lb/N per acre credit (similar to EU credits), which was derived as ten percent of the first nitrogen discharge limit of 300 pounds of nitrogen per acre (Attachment A, Page 154). The second option is based on field trials conducted in the Central Coast, and is a calculated credit estimated at 97% of shoot N content. Both credits have three requirements: that the cover crop be non-leguminous, that it grow for at least 90 days between October and April (during the winter fallow period), and that it accumulates more than 4500 lb/acre dry biomass. In addition, the second calculated option requires that the cover crop have a C:N requirement greater than 20:1.

Estimates of how nitrogen mineralization differs across California soils suggests that a single value for nitrogen mineralization rates may not apply statewide. This would make it difficult to develop a single statewide discount factor for how much nitrogen would be mineralized from organic amendments. The need to take soil-specific factors into account is a large part of Danish nitrogen mineralization forecasts (Q4), which produces different values for three of the main agricultural soils in the country. Variables that impact N mineralization in California soils include soil texture, organic matter content and soil C:N ratio.

The soil-specific factors that impact nitrogen mineralization also impact the emission of nitrous oxide and NO_x from California soils (currently included under R_{OTHER} in Ag Order 4.0 calculations). These gaseous nitrogen emissions, which can be comparable to the nitrogen potentially lost to leaching depending on the region and farming practices, can also have significant impacts on air quality for underserved communities in the Central Valley. This is particularly true in clay-textured soils which can more easily become anaerobic. Better measurement and modeling of these emissions, particularly in the context of agricultural practices such as drip irrigation, are necessary for more accurate estimations of nitrogen balances.

Question 7B: Does including the discount factors allow for a full accounting of the nitrogen that has the potential to discharge to groundwater?

As outlined in Q3 and the 2014 EAP report, representing every nitrogen transformation that takes place in an individual field will be fraught with error and unnecessary expense. The difficulties for experts are tremendous, and are unrealistic expectations for farmers. Therefore, capturing and accounting (such as through discount factors) for every nitrogen transformation in a field that has the potential to leach to groundwater may not be feasible, unless detailed site-specific models can be created and maintained.

However, as outlined in Mclellan et. al 2018, N balances had a strong relationship with environmental N losses and served as a robust measure of nitrogen losses that is simple to calculate, easily understood, and based on readily available farm data. This result suggests that accounting for all sources of nitrogen addition and loss may not be necessary, as long as the biggest sources of nitrogen addition and loss are accounted for.

Question 7C: Will including these additional components of R result in valid and comparable A/R and A-R values between different growers?

California results have shown that, due to climate and soil type differences, the rate of nitrogen mineralization from soil organic matter varies across the state. Accurately calculating nitrogen inputs and removal for a specific field would need to take these varying rates into account. However, even if growers are in different locations, and so have different values for N supplied from organic matter mineralization in a year, comparisons are still possible. EU results suggest that the most important factor for comparing between states (or growers) is using the same method/formula to calculate nitrogen budgets in each location.

As outlined in Q1B, nitrogen fertilizer limits are calculated differently in almost every EU member state. A comparison of regionally calculated nitrogen budgets across European countries showed that it was difficult to draw firm comparisons, since methods as well as data vary across states. Another comparison of EU limits showed that one of the most important factors for a comparison is having a standardized formula to calculate N limits that is used across regions.

Question 7D: Is incentivizing the use of nitrogen in irrigation water by excluding it from the calculation of total nitrogen applied the most appropriate approach for accounting for and controlling potential discharges to groundwater and reducing the overall concentrations of nitrates in groundwater?

Ag Order 4.0 included nitrogen discharge calculation options that excluded irrigation water nitrogen in order to incentivize the use of nitrogen in irrigation water for crop growth. This is in recognition of research showing that the nitrogen present in the irrigation water is “at least as effectively used by the crop as fertilizer [nitrogen]”. In one study looking at nitrate vulnerable zones in Portugal, nitrogen inputs from irrigation water were as high as 84 lb N/acre/year. Data in review from the Central Valley of California also found that irrigation water nitrate concentrations varied between 1 to 8 mg/L nitrate-N over 2 years. The importance of accounting for nitrogen from irrigation water is likely dependent on the nitrogen concentrations in that water, which in turn is dependent on the location that water is drawn from. Improved irrigation management that keeps water in the root zone can significantly reduce both gaseous and leaching nitrogen losses, given that the amount of nitrogen leached is also highly dependent on the amount of water available.

Question 8: Is there enough data and scientific research to conclude that small and/or small diversified farms are operated in a fundamentally different manner that results in a reduced water quality impact compared to larger farms, on a per acre basis? If yes, what criteria could be used to identify the operations that have reduced water quality impacts?

One overarching definition of a diversified system is one that cultivates social and ecological complexity to provide multiple ecosystem services, maintain management flexibility, and promote adaptation. In practice, this diversification can take many forms, including the use of in-field practices such as crop rotation, cover cropping, livestock integration, agroforestry, and intercropping. It can also refer to the diversification of the people farming, with evidence showing that new-entrant and socially disadvantaged farmers (e.g., women, immigrants, racial/ethnic minorities, and young farmers) may be more willing and likely to adopt diversified farming practices. Global surveys of diversified cropping systems (admittedly with varying definitions of "diversified") have shown positive impacts on ecosystem services, including drought resistance, water quality and nutrient cycling, and neutral to positive impacts on yield. California's recent focus on "regenerative agriculture" also includes a focus on diversifying agricultural systems.

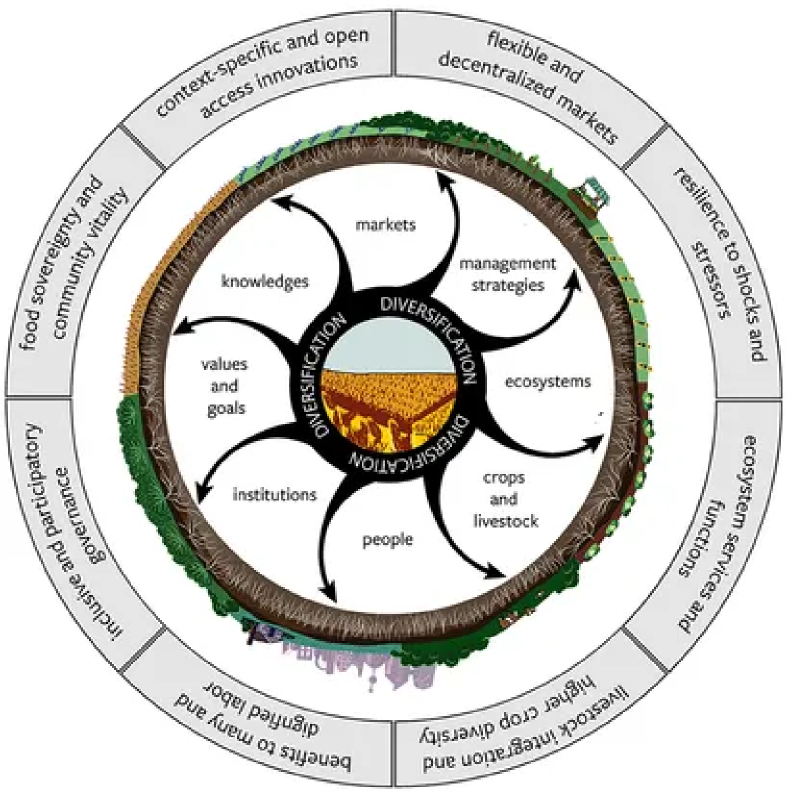

Fig. 7. A conceptual diagram of the multiple areas of progress needed to move from simplified (center of wheel) to more diversified farming systems (outer ring of wheel). Taken from Petersen-Rockeny et. al 2021.

Water Quality Impacts of Diversified Farming Systems

Literature suggests that diversified farming systems can reduce the need for nitrogen inputs while maintaining yield, reduce potential for nitrogen leaching, increase nitrogen mineralization, and reduce the potential for erosion (a major source of turbidity in aquatic systems). A large portion of the nitrogen-related benefits from diversified farming systems comes from the potential for more nitrogen mineralization associated with increased crop diversity and increased organic matter. Plant N availability within a growing season may be more closely related to the rate of turnover and cycling of nitrogen than to the size of soluble N pools in the soil. Cropping systems have shown markedly increased N mineralization rates even with the addition of a single crop to a rotation, with one estimate showing that a soybean-corn cropping system was found to increase potentially mineralizable N by up to 33%, and reduce soil inorganic N pools by up to 28%, while simultaneously increasing corn yields by 4% compared to a corn-corn cropping system. Another study found that a corn-soybean-sorghum-oat/clover rotation had a mineralization rate 3.9x higher than a corn-corn rotation, and that nitrogen fertilization decreased this positive impact. The release of nitrogen from organic matter can provide a substantial amount (between 64-89% of N needs by one estimate) of bioavailable nitrogen, which can, in soils with sufficient organic matter and an active microbial community, decrease the need for soluble nitrogen application via fertilizer. The increased potential for N supply from organic matter, and the potential for decreased inorganic N pools in the soil at the end of the cropping season in diversified cropping systems can in turn reduce the potential for nitrogen to be leached into the environment.

Diversifying farming systems can also include the use of cover crops to both reduce nitrogen leaching and reduce erosion in periods that the soil would have been left uncovered. While the impact of cover crops on gaseous nitrogen losses is mixed depending on climate, moisture and cover crop grown, they have been shown to reduce the potential for nitrogen leaching and to have minimal impacts on winter water loss from soils in California. Diversified (20+ crops grown) farms in California were also found to harbor more diverse mycorrhizal fungi populations, which can increase the amount of soil scavenged for nitrogen and potentially reduce soluble N pools susceptible to leaching.

Impacts of Small Farms

The question of whether small farms inherently have smaller environmental impacts depends on the farming systems in question. Small farms are more likely to harbor greater crop and non-crop biodiversity, but may not inherently differ in either resource use efficiency or gaseous nitrogen losses. An example study of small farms in Germany indicated that they are more likely to diversify farm products and be managed differently, but may be less likely to adopt practices such as cover cropping or edge-of-field buffers, potentially due to limited land availability and the cost associated. In the California context, small farms are often associated with immigrants with a variety of cultural perspectives and language barriers, new-entrant and socially disadvantaged farmers; who in turn may be more likely to adopt diversified practices. It is also worth noting that German nitrogen regulations are relaxed on farms smaller than 38 acres that meet other criteria, and New Zealand nitrogen application limits do not apply to farms smaller than ~50 acres (Q9).

Question 9: As summarized in footnote 33 of the Central Coast Ag Water Quality Order, the Eastern San Joaquin Water Quality Order contains exemptions from its precedential nitrogen management requirements for growers whose nitrogen-related practices do not impact water quality, and also gives the regional boards the discretion to allow additional time or alternative methods for three categories of growers to submit their R data. Is there enough data and scientific research that would support any other exceptions to, or alternative methods for complying with, the precedential nitrogen management requirements in the Eastern San Joaquin Water Quality Order or any nitrogen-related limits or other requirements recommended by the Expert Panel?

Ag Order 4.0 Exemptions

As outlined in Part 2, Section C.1 (21-24), the remanded Ag Order 4.0 contains several exemptions from both the fertilizer application and N discharge limits. Growers able to show that they are meeting final nitrogen discharge limits (50 lb N/acre) are exempt from fertilizer application limits and submitting nitrogen removed reports, while growers that submit a technical report showing that their farms pose no threat to surface or groundwater quality are exempt from most reporting requirements. Growers that can directly monitor nitrogen runoff at the point of discharge can use this monitoring approach to comply with final N discharge limits instead of using the A-R formula. As outlined in Part 2, Section C.2 (1), dischargers who are members in good standing with a third-party alternative compliance pathway program are not subject to the fertilizer application limits or the nitrogen discharge limits.

EU Nitrate Directive Exemptions

At the country level, the EU Commission may grant "derogations" to member states allowing them to apply more nitrogen from manure than the standard 170 kg/ha allowed under the EU Nitrates Directive, provided the member state can scientifically justify that the higher application will not lead to increased water pollution. Even with exemptions, Member States must still meet the Directive's water quality objectives and other requirements. There is currently a derogation still in force for Ireland, while the Netherlands and Denmark recently allowed their derogations to expire.

In order to receive these exemptions, the member states have to specify the nature of the exemption and estimate how positive environmental outcomes will still occur- these justifications do not appear to include data on agricultural productivity. For example, Denmark's previous exemption allowed it to apply 230 kg nitrogen per hectare per year, subject to conditions including the planting of catch crops, phosphorus ceilings, crop rotation, application of manure and other fertilisers, and soil sampling. The data submitted to justify this exemption includes showing that the majority of surface and groundwater monitoring sites have nitrate concentrations below the 11.3 mg/L nitrate-N EU target, and that nitrate concentrations are either remaining stable or decreasing over time.

Ireland's current exemption allows farmers to apply livestock manure up to a limit of 250 kg nitrogen/ha per year on farms with at least 80% grassland. The data submitted to justify this exemption was similar to Denmark's: surface and groundwater monitoring site data, trends in nitrate concentrations and number of surface water bodies suffering from eutrophication. The Irish exemption also outlined that their long growing seasons and high yields of grass with high nitrogen uptake warranted increased nitrogen application.

EU Country-Specific Exemptions

Given that EU countries implement nitrogen limits differently (Q1A), there are also different exemption criteria within countries. For example, fertilizer regulations in Germany exempt farms that meet all of the below criteria from nitrogen regulations:

1) Smaller than 15 hectares (~38 acres)
2) Only grow vegetables, hops, grapes or strawberries on 2 hectares
3) Apply less than 750 kg of N from animal manure (max 50 kg/ha, or 48 lb/acre)
4) Do not apply fertilizer derived from biogas digesters located outside the farm

Danish regulations exempt farmers from manure N limits if they make less than ~$7500.00 from agricultural activity, or if their farms meet none of the following criteria:

1) Has more than 10 livestock units
2) Has more than 1.0 livestock unit per hectare
3) Receives more than 25 tonnes of livestock manure per year

In the Flanders region of Belgium (an area that has experienced significant nitrogen pollution), there are restrictions on timing of fertilizer application that exempts certain crops. Flemish farmers are allowed to apply the 170 kg N/ha limit separately to different crops if they plant at least two horticultural crops in the same calendar year, effectively doubling their fertilizer application limit. This is similar to what was proposed in Ag Order 4.0 (Table C.1-2). Additionally, the Flemish government also allows for additional compost that would exceed the N application limit to be applied to plots with low carbon contents, provided that residual nitrate tests show less than 90 kg N/ha remaining in the plot before application.

NZ Exemptions

New Zealand regulations exempt all farms smaller than 20 hectares, or farms with no grazed land (i.e arable crop farms) from the 190 kilograms of synthetic nitrogen per hectare limit.