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TRANSITIE COALITIE voedsel

Robin Food Coalition

The Hidden Bill

An analysis of the societal costs of Dutch agriculture today versus alternative systems

October 2025

Contents

Foreword

The Netherlands is widely recognised for its productivity and efficiency in agriculture.

Despite being a small, densely populated country with limited land, we punch well above our weight in global markets. So much so that, after the US, the Netherlands is the second largest exporter of agricultural products by value.

Yet the sheer scale and intensity of our current agricultural system means that, behind its success, there are hidden costs to our society.

Intensive production is polluting our air and water, exhausting our soil and harming our biodiversity. The use of water resources is escalating. And, as a high emitter of greenhouse gases (GHGs), the sector is also a contributor to climate change.

These negative impacts affect the health both of our people and of the essential ecosystems on which we, and our farmers, ultimately depend. In the longer-term, unchecked environmental damage could threaten the stability, resilience and economic viability of the agricultural system itself.

The monetary value agriculture generates and contributes to GDP is relatively easy to measure with tried and tested economic methodologies.

However, less easy to measure are the significant costs the system imposes on society, for example through healthcare and the repair of environmental damage. These societal costs, partially paid by public spending and insurance payouts now, but largely deferred to future generations, have been largely out of sight.

Robin Food Coalition and the Food Transition Coalition have commissioned Deloitte to develop a report which provides insights into the hidden societal costs of agricultural production in the Netherlands. The result is a thorough societal cost-benefit analysis.

Starting from the current business-as-usual model, the study assesses a sequence of four alternative systems that build upon each other.

In the first three alternatives, we assess the cumulative effects of full organic conversion as a proxy for lower-impact farming; the introduction of smart innovation and a decisive shift toward plant-based protein production.

Finally, we explore an additional rather hypothetical scenario in the mid-term to bring the agricultural system within its ecological planetary boundaries through reduced production levels.

We examine each alternative system not only for its economic performance, but also for its ability to regenerate soils, reduce external dependencies, buffer climate extremes, address water issues and safeguard public health—all foundations of a resilient food system.

Our goal is to contribute to the ongoing debate about the future of Dutch agriculture. We hope this research provides useful insights on how the hidden societal costs of agriculture could be reduced and how the long-term resilience of the system could be enhanced.

We are grateful to our research team and to the scientists and external experts who contributed data and critique. Their collective effort demonstrates that, despite the obstacles, systemic change towards net positive impact is achievable, albeit requiring significant commitment from all stakeholders.

We invite politicians, provincial leaders, retailers, investors, insurers and Dutch citizens to use this research as a reference point. By redesigning incentives, scaling organic practices and implementing smart solutions, we can start moving towards a long-term resilient, healthy and net-positive agricultural system.

Let us channel Dutch ingenuity toward building an agricultural system that delivers genuine positive impact economically, socially and environmentally.

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Executive Summary

Executive Summary | The Hidden Bill

Transitioning to a smarter, lower-impact agricultural system can shift the current balance from net negative to net positive. However, this will require deliberate, well-sequenced policy reform and targeted investments

This study compares the economic benefits and societal costs of the current Dutch agricultural system with a cumulative series of four alternative systems. By putting a monetary value on both economic benefits and societal costs, we gain holistic insight into the true impacts of agriculture. We can understand where today's system succeeds, and where its costs to society have implications for long-term prosperity.

The status quo: High returns, higher societal costs - € 5.3 bn

Dutch agriculture sets a global productivity benchmark, yet our analysis shows that its yearly contribution to GDP is outweighed by the societal costs it imposes. In particular, its emissions of GHGs and nitrogen (including ammonia) and its land use impacts on biodiversity —driven largely by dairy, beef and pork production —help to create a net negative impact.

Alternative 1: Low-impact farming - € 1.0 bn

Converting all production to methods with lower environmental impacts, for which we use organic as a proxy, would lower environmental impacts, restore soil function and increase on-farm biodiversity. The transition to 100% organic would be a large step-up from currently ~5% of land use and offer significant challenges with regards to lower output per hectare, land availability for feed production, farmer business cases and consumer prices.

Alternative 2: Low-impact farming with smart innovation + € 2.7 bn

Introducing precision technologies, electrified equipment and advanced water management tools into a fully organic system reduces the yield losses. Our model suggests that innovation can absorb part of the productivity penalty while materially reducing emissions and water withdrawal.

Alternative 3: Protein shift + € 5.3 bn

Re-orienting production towards 70 percent plant protein and 30 percent animal protein lifts total protein output and slashes ammonia and GHG emissions. Some pressures—such as nutrient run-off and certain land use impacts—could intensify if not carefully managed, but the overall costs to society drop markedly.

Scenario: Reduced production (Alternative 4) + € 5.3 bn

Enabling the system to operate within its planetary boundaries would require production to be capped at levels consistent with the Netherlands' share of global ecological limits. This, in the mid-term rather hypothetical, scenario would deliver the steepest reduction in environmental impacts and related societal costs.

Protein output would fall by around 60 percent relative to today, and economic value added would reduce accordingly. However, GHG emissions, nutrient surpluses and habitat pressures all would retreat into a genuinely sustainable range. Of all the alternative systems analysed, it would offer the clearest path to long-term ecological resilience.

The implementation of the alternative systems at full would come with significant challenges. The modelling thereof should rather give direction and serve as a touchstone for future decisions.

Implications

Taken together, the results demonstrate that:

- Meaningful reductions in societal costs are achievable without sacrificing food security, provided the system shifts towards low-input practices, technology-enabled efficiency and a decisive plant-protein focus.
- While incremental measures can deliver significant improvements in environmental impacts and related societal costs, they are insufficient to bring the system entirely within its ecological limits. Doing so would ultimately require a smaller, smarter and more diversified agricultural footprint.
- The transition to an agriculture system within planetary boundaries would come with significant disruption to the sector's earning potential and related employment, farmer economics, and consumer prices and consumption shifts, if not carefully managed.
- On the positive side, the transition inhibits opportunities for the Dutch agri sector to become a front-runner in high-value, low-impact food and agritech sectors.
- To navigate the challenges and opportunities, the transition demands a deliberate and well-sequenced combination of policy reform, targeted investments, market incentives, and close collaboration across the value chain by key stakeholders.

Reducing the societal costs of Dutch agriculture

- The current Dutch agricultural system has an annual net negative impact of **- €5.3 bn** when its costs to society are offset against the economic benefits it generates.
- These costs could be reduced, and a net positive impact of **+ € 5.3 bn** achieved, through a cumulative series of alternative farming systems.

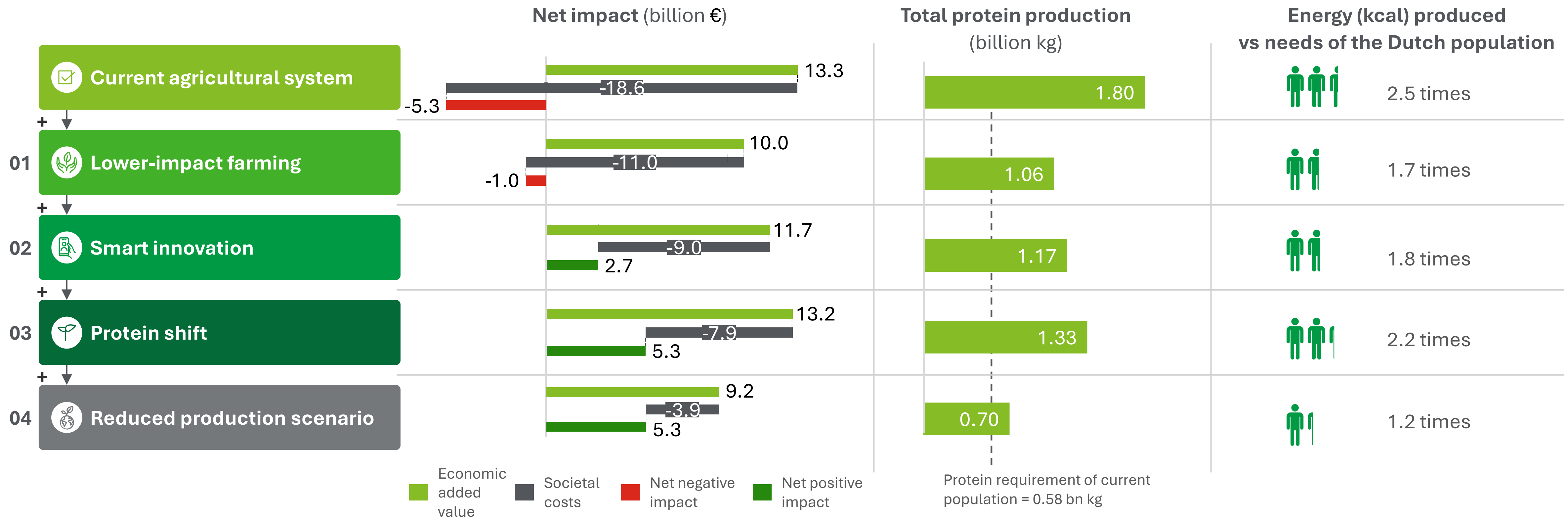
	Current system	01 Low-impact farming	02 Smart innovation	03 Protein shift	04 Reduced production scenario
Net impact (Economic benefits minus societal costs)	**- € 5.3 bn**	**- € 1.0 bn**	**+ € 2.7 bn**	**+ € 5.3 bn**	**+ € 5.3 bn**
Description	Current agricultural area and yield as baseline for the analysis	+ Adoption of 100% organic farming[1]	+ Introduction of smart technological innovations	+ Production shift to 70% plant-based and 30% animal protein	+ Production reduced by almost half to operate within planetary boundaries
Farm type:	Conventional	Organic	Organic	Organic	Organic
Innovation:	Current state	Current state	Innovative	Innovative	Innovative
Protein production:	60% animal – 40% plant	43% animal – 57% plant	39% animal – 61% plant	30% animal – 70% plant	30% animal – 70% plant
Production area:	1.80 m ha	1.80 m ha	1.80 m ha	1.80 m ha	0.95 m ha

[1] We use organic agriculture as a proxy to quantify farm systems that have lower environmental impacts. More information here.
[2] The model focuses on the costs and benefits of primary agricultural production in the Netherlands and of its key imported inputs. More information here.

Shifting the system towards net positive impact

Introducing a cumulative series of alternative agricultural systems could shift primary production to a net positive impact while continuing to provide the nutritional requirements of the Dutch population.

1. Adopting 100% low-impact (organic) farming could cut the societal costs of today's agricultural system by 41%
2. Adding smart innovation would reduce societal costs by a further 10% and create a net positive impact
3. Shifting towards 70% plant-based protein production would cut societal costs by 58% and create a net positive impact of €5.3 billion



Performance against planetary boundaries

For the agricultural system to operate within its planetary boundaries, production would need to be almost halved after implementing the first three alternative systems at full

- Adopting low-impact farming methods, introducing smart innovation and shifting to 70% plant-based protein production would not be enough to bring the system within all its key planetary boundaries.
- To operate within planetary boundaries, production would need to be almost halved following implementation of the first three alternatives.
- Achieving this would require an additional step of almost halving (-47%) the land area used for production (presented in this analysis as Alternative 4: Reduced Production).

Falls within planetary boundaries (Yes / no)

		Climate change	Phos-phorous	Nitrogen	Water use	Land use
	Current agricultural system	511%	103%	235%	9%	32%
01	+ Lower-impact farming	348%	81%	142%	5%	19%
02	+ Smart innovation	228%	89%	137%	4%	19%
03	+ Protein shift	190%	100%	120%	4%	19%
04	+ Reduced production scenario (-47% production)	100%	53%	63%	2%	10%

No (more than 100%): 511%, 103%, 235% (current); 348%, 142% (01); 228%, 137% (02); 190%, 120% (03)

Yes (less than 100%): all other values

Conclusions and recommendations

Key levers to reduce the societal costs of agriculture include system reform, investment in innovation, support for farmers and consumer engagement.

Conclusions

- While **the current Dutch agricultural system** delivers strong economic benefits (€13.3B), it also imposes high costs on society (€18.6B), resulting in a **net negative impact**.
- Shifting to a **combination of alternative systems** (alternatives 1-3), including shifting towards low-input practices, technology-enabled efficiency and a decisive plant-protein, could significantly reduce the impacts and turn towards a **net positive impact**, while **assuring food security** in the Netherlands. At 100% implementation, the economic value add will remain about current levels whilst **societal costs drop by -58%.**
- Operating within **planetary boundaries** would be highly challenging, requiring significantly reduced production (**-61% total protein production** versus current state, and even -80% animal-based protein). This would reduce the number of farms, employment, financial turnover and exports, with knock-on effects across the entire agricultural sector.

Considerations

- Transitioning to alternative agricultural systems would have a significant impact **on farmer business case, sector revenue, exports and employment**. It could also potentially limit the **variety of production and nutrient supply** and create **affordability challenges for consumers**
- On the positive side, shifting to alternative systems could **catalyse new business opportunities** for in food and agtech, would **reduce dependencies on imports by 50% and free up land** which can be used for housing, nature and a healthier living environment.
- The modelling assumes the applicability of the same measure across all food categories, and is limited to the Netherlands only. By **optimizing the measures per category** and taking into account the **different farming conditions per product group across Europe**, the net impact can be further increased and food security and variety further enhanced.
- The transition would require significant **investment, innovation and long-term policies.**

Recommendations

Reform policies:
Reform financial and fiscal incentives to reward lower-impact practices.

Invest in innovation:
Develop smart technologies and nature-based solutions to optimise yields and minimise environmental impacts and societal costs.

Support farmers:
Support farmers in transitioning to lower-impact production, for example through access to capital, retraining and risk protection tools.

Engage consumers:
Promote acceptance of sustainable, healthier plant-based diets and ensure equitable access to nutritious food.

Align internationally:
Address potential environmental leakage by coordinating with trade partners on sustainability standards.

Introduction

About this report

Objectives of this analysis

We quantify hidden societal costs in Dutch agriculture and explore how to shift the system to net positive impact

The ability of a nation to feed its people ultimately depends on vital resources such as healthy soil, access to clean water and a stable climate.

If these essential foundations of farming are weakened, then the stability of the entire agricultural system could be at risk.

There are hidden costs in today's agricultural system

The Netherlands offers a striking example. On scarcely two million hectares, Dutch farmers and horticulturalists deliver some of the world's highest yields and export products worth well over €80 billion. The sector contributes significantly to Dutch Gross Domestic Product (GDP) and supports tens of thousands of jobs.

Yet, behind this success story, are hidden costs for society. Emissions of nitrogen and greenhouse gases (GHGs) are accelerating beyond safe thresholds. The quality of our soil and biodiversity are declining (WUR, 2024). Climate change, the pollution of air and water, and the depletion of our resources are all worsening and leading to environmental and social problems (EEA, 2025). In terms of public health, diet-related diseases are adding another layer of cost to society (RIVM, 2021).

These impacts have profound implications for policymakers as well as for Dutch society.

Societal costs currently outweigh economic benefits

To better understand the scale of the challenge, we – Deloitte, Robin Food Coalition (RFC) and the Food Transition Coalition (TcV) – have conducted a societal cost–benefit analysis of the Dutch agricultural sector.

We set out to quantify the hidden societal costs of our current agricultural system and compare them with the economic benefits.

We found that, when expressed in monetary terms, **the societal costs of food production outweigh the economic value the system contributes.** In fact, **the net negative impact exceeds €5 billion** per year.

This analysis explores ways to reach net positive impact

In this analysis, we explore how the societal costs of the Dutch agricultural system could be reduced. Our goal is to identify potential pathways to net positive impact when offsetting societal costs against economic benefits.

The analysis is based on a cumulative sequence of four alternative agricultural approaches. As each alternative is introduced to build on the preceding one, we assess the economic, social and environmental effects that would result and benchmark them against those of the current system.

The four, cumulative alternatives are:

- Low-impact farming
- Smart innovation
- Protein shift
- Reduced production (hypothetical scenario)

For each alternative, we apply three key benchmarking measures:

- **Economic benefits** (economic added value through primary production)
- **Societal costs** (total costs to society beyond direct financial costs to farmers or businesses)
- **Nutritional value** (total protein and energy produced; capacity of the system to feed the Dutch population)

More on our analysis model and methodology.

Could the system operate within planetary boundaries?

Planetary boundaries are quantifiable limits to the stability of the Earth's critical ecological systems. When planetary boundaries are breached, the long-term safety of humanity is threatened.

We found that the current Dutch agricultural system exceeds three of five key planetary boundaries. Our analysis, therefore, also tests the proposed alternative systems through a planetary boundary lens and explores options for the system to operate within safe boundaries.

More on planetary boundaries and our assessment methodology

This report contributes new insights to an important debate

Our objective in publishing this report is to enhance the ongoing debate about the future of farming with transparent, fact-based data that helps to move discussions from ideology to evidence.

While the alternative systems proposed might be challenging to implement at 100%, the analysis provides new insights on how the negative impacts of today's agricultural system could be reduced, and how the system could be adapted to operate within planetary boundaries.

This information may be of use to multiple stakeholders including farmers, businesses, financial institutions, government and civil society.

We believe the report breaks new ground by assessing the societal costs and benefits of the Dutch agricultural system in its entirety, rather than focusing on a specific segment or production category.

Transitioning towards alternative systems is not straightforward and is costly. We therefore also provide evidence-based, actionable options for policymakers and market actors.

Our impact analysis model

The model compares the economic, social and environmental costs and benefits of today's agricultural system with a sequence of alternatives.

Agriculture delivers many benefits to society, including its economic contribution to GDP and the nutritional value of the food produced. Conversely, it also incurs costs on society including public healthcare and the repair of environmental damage. These costs are typically funded through taxes or insurance and are mostly deferred to future generations.

Our model analyses these costs and benefits, both in the existing Dutch agricultural system and in four cumulative alternative approaches. The model assumes a 100% implementation of the approaches across the Dutch agricultural system. Especially alternative 1 "Low-impact farming" and alternative 4, "Reduced Production Scenario", might in the mid-term be rather hypothetical given the massive challenges and disruptions involved. The modelling should therefore not be seen as a set of prescriptive actions, but as a touchstone for future decisions.

Economic benefits

The model calculates the economic benefits of the current agricultural system and alternatives in value added terms. In this way, it provides insight into the economic viability and financial implications for farmers. It takes into account:

- Value added at farm-level
- Production volumes
- Price fluctuations
- Operational and input costs

More on the economic benefits included in this analysis and calculation methodologies

Societal costs

The model puts a monetary price on the impacts of agriculture on society that are not reflected in the market or product pricing. In this report, the term 'societal costs' refers to the total cost of food production to society beyond the financial costs directly incurred by farmers and agricultural businesses.

These societal costs include:

- **Environmental impacts** such as soil degradation, water and air pollution, biodiversity loss and GHG emissions
- **Social consequences**, including negative health effects and increased healthcare costs
- **Expenses** related to cleaning up pollution and other environmental damage, managing public health and mitigating climate change.

The analysis derives social and environmental impacts from life cycle assessment (LCA) data and monetises them using shadow prices that estimate damage to health, ecosystems, materials and well-being.

Not all the societal costs of food production are covered. The analysis excludes some because they remain constant between the alternatives explored and therefore provide limited insights for comparison. Others are excluded because they cannot be quantified robustly in monetary terms or because they cannot be attributed directly to agricultural production.

More on the societal costs included in this analysis and calculation methodologies

Nutritional value

Nutrition is the primary benefit agriculture brings to society. The analysis therefore measures and compares the nutritional value provided by the current system and the potential alternatives. It measures nutritional value in the following ways:

- Total protein produced (kg)
- Total energy produced (kcal)
- Capacity to feed the Dutch population

More on the methodology used to assess nutritional value

Benefits and costs considered in the model

This analysis quantifies the economic benefits and societal costs of the Dutch agricultural system, including the nutritional value it provides.

	Economic benefits	Societal costs	Nutritional value
In scope	• **GDP (at farm-level):** Total economic added value generated by agricultural activities directly on the farm • **Effects on import and export:** Potential effects on the import of inputs (e.g. energy, fertiliser, animal feed) and export of food products.	Costs paid by society to address environmental damage and public health issues caused by the Dutch agricultural system. These costs are typically borne through taxes and insurance. The model includes societal costs related to the following environmental impacts: **Climate change (CO_2-eq):** GHG emissions, such as carbon dioxide and methane • **Nitrogen (N-eq):** Eutrophication by nitrogen compounds. • **Phosphorus (P-eq):** Eutrophication by phosphorous compounds. • **Ammonia (NH_3)[1]:** Ammonia gas released into the air. • **Water consumption:** Water consumption in farming processes. • **Land use and biodiversity loss:** Biodiversity loss refers to losses in species abundance and ecosystem services caused directly by land occupation. It does not include losses from other drivers such as ammonia, emissions, or soil or air pollution, which are assessed separately. • **Air pollution (particulate matter):** Release of fine airborne particles during farming, including $PM_{2.5}$ and PM_{10}. • **Pesticides[1]:** Human health issues caused by chemical substances for crop protection. • **Soil health[1]:** Condition, fertility and biological activity of agricultural soils.	• **Produced protein** • **Produced energy (kcal)** • **Energy production in relation to the needs of the Dutch population**
Not in scope [2]	• **Broader GDP:** Broader macro-economic changes beyond primary production. • **Employment and labour market changes** • **Household spending and effect on consumer prices**	• **Animal welfare:** Well-being of animals. • **Microplastics and other novel entities:** Mitigating pollution from plastics and other novel entities. • **Human rights:** Issues such as fair wages and working conditions. • **Overweight and obesity:** Healthcare expenses and productivity losses related to overweight and obesity • **Other diet-related health costs:** Expenses and productivity losses related to diet-related diseases, mental health impacts, foodborne illnesses, and antimicrobial resistance. • **Zoonotic diseases:** Public health impacts from zoonotic disease outbreaks.	• **Food waste** • **Nutrient density and food quality**

[1] For these environmental impacts, a high-level analysis is conducted for each alternative to assess the potential societal costs. These impacts are not detailed per product category.
[2] These impacts are not included in our assessment because they are either not expected to change significantly between alternatives, are difficult to quantify or monetise unambiguously, or their societal costs cannot be directly attributed to primary agricultural production. Some factors also fall outside the defined system boundaries.

Boundaries of the analysis

The model focuses on the costs and benefits of primary agricultural production in the Netherlands and of its key imported inputs

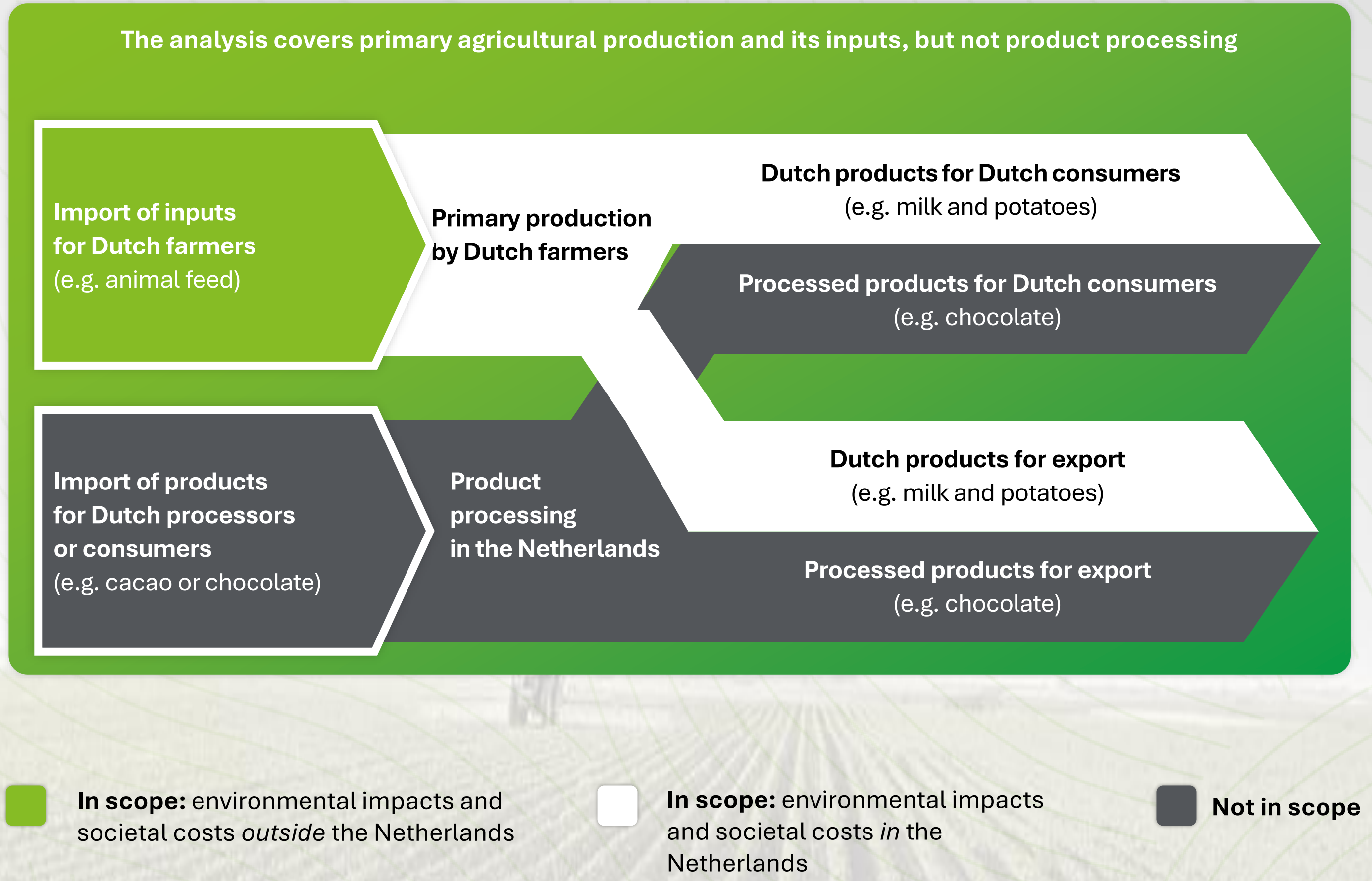
Boundaries of the analysis

The analysis includes:

- Food produced for domestic and export human consumption by Dutch arable farming, greenhouse horticulture and livestock farming.
- Key imported inputs, such as animal feed and fertilisers.

It excludes:

- Products imported for Dutch consumers or re-export.
- Product processing, logistics and consumer activities such as cooking.
- Food processed in the Netherlands, but not grown or raised there (e.g. cacao).



Baseline analysis of current Dutch agriculture

Results | Benefits and costs of current Dutch agriculture*

Today's Dutch agricultural system delivers a **net negative impact of - €5.3 billion**, when offsetting societal costs against economic benefits.

Economic benefits

€ 13.3 billion

(value added to the Dutch economy through primary agricultural production**)

...

1.4%

share of total Dutch GDP

The economic output of primary production is significant, but limited compared with the GDP contribution of the wider sector*** (6.9%).

...

* Data used to define the current Dutch agricultural system is from 2022
** within the total Dutch agricultural system (Ministerie van LVVN, 2022, visited May 2025)
*** Wider sector includes primary production, distribution, processing and supply sector

Societal costs

Societal costs

€ 18.6 billion

Environmental impacts and societal costs related to primary production exceed current economic benefits.

Societal costs per environmental impact for the current state (€bn)

Climate change	-€ 7.9
Phosphorus	-€ 0.1
Nitrogen (inc. ammonia)	-€ 7.2
Water consumption	-€ 0.1
Land use and biodiversity loss	-€ 2.5
Particulate matter	-€ 0.5
Pesticides	-€ 0.4

Nutritional value

Dutch agriculture produces more than twice the protein and energy the Dutch population needs.

Protein production[1] in the Netherlands

1.8 billion kg

60% Animal-based[1]

40% Plant-based[1]

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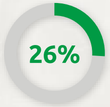


Over a quarter of protein production is derived from raw milk.

...

Total kcal production can feed the Dutch population 2.5 times

[1]Based on yield per product group (in kg) and amount of protein per product group (in kg/kg). See Methodology.

Results | Climate change and air pollution are the primary drivers of societal costs

The estimated annual societal costs associated with current Dutch primary production are shown below, broken down by impact category and product group.

Climate change and ammonia air pollution are the dominant costs

A majority of these costs result from the sector's climate change impact (€7.87 billion/year) and air pollution by ammonia (€5.85 billion/year, which is caused by nitrogen from animal manure. Nitrogen pollution also contributes to significant water pollution costs (€1.30 billion/year).

Biodiversity loss is significant

Biodiversity loss, mainly driven by intensive agricultural practices, incurs a substantial societal cost of €2.46 billion/year.

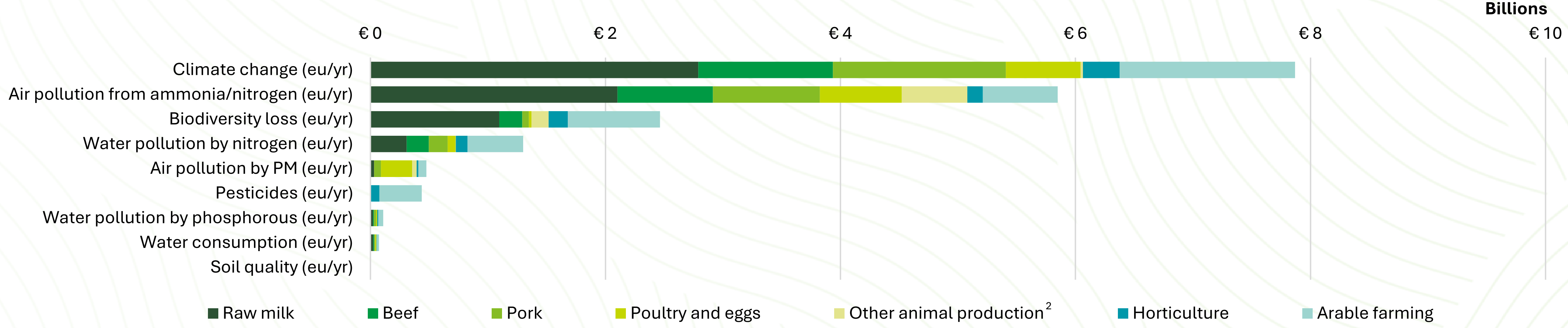
Animal-based products drive the highest costs

Animal-based products, particularly raw milk, beef and pork, are responsible for the largest share of all major societal cost categories: specially climate change, air pollution and biodiversity loss. Plant-based foods generally have lower societal costs than animal-based products. However, intensive horticulture and high production volumes of some plant-based foods (e.g. sugarbeet) can also pose environmental challenges.

Other environmental costs are lower, but notable

Societal costs related to pesticide use (€440 million/year), particulate matter (PM) air pollution (€0.48 billion/year) and phosphorous pollution (110 million/year) are lower, but still significant. The environmental impact of water consumption currently carries a relatively low societal cost in the Netherlands, but this could increase in the (near) future due to climate change.

Societal costs resulting from environmental impacts of current Dutch agriculture, per product group (in bln €)[1]



[1] Societal costs are incurred primarily in the Netherlands, but partially in other countries that produce inputs for Dutch agriculture, such as animal feed and fertilisers.
[2] Societal costs related to all livestock farming other than beef, pork and poultry, e.g. goats and sheep.

Alternative agricultural systems

Alternative systems | Options to reduce the societal costs of Dutch agriculture

Alternative configurations of the Dutch agricultural system could shift the system to net positive impact

As detailed in the previous section, the current Dutch agricultural system generates a net negative impact valued at -€5.3 billion when its societal costs are offset against its economic benefits.

In this analysis, we explore a cumulative series of four alternative system configurations with the potential to shift the balance towards net positive impact. Our goal is to provide insight into how the Netherlands could reduce the negative environmental impacts of agriculture and their associated costs to society.

These alternatives, if introduced in the sequence suggested, reflect a logical progression. Each step builds on the previous one and introduces a key lever to reduce societal costs.

Four alternative configurations for Dutch agriculture

1. Low-impact farming: Transition to farming practices with low environmental impacts. For this analysis, we use adoption of 100% organic farming in the Netherlands as a proxy for this transition.

2. Smart innovation: Incorporate proven smart innovations to further reduce environmental impacts and increase yields. We focus on feasible improvements grounded in today's possibilities rather than speculative or untested future solutions.

3. Protein shift: Shift the balance of production towards plant-based rather than animal protein (The Netherlands currently has a disproportionately large animal agriculture sector). Achieving this shift would require structural changes in production because changes in consumer behaviour alone would be insufficient to drive transformation at scale.

4. Reduced production scenario: We explore what it would take for the agricultural system to operate within planetary boundaries. Limiting agricultural production would a key condition. This analysis attributes planetary boundaries proportionally to the Dutch population size. This alternative is hypothetical in the mid-term given the disruptions to the sector, farmers and consumers expected. Therefore, we consider it a scenario providing direction rather than a solid alternative for now.

Proposed alternative configurations for Dutch agriculture

		01	02	03	04
	Current system	Low-impact farming	Smart innovation	Protein shift	Reduced production scenario
Description	Current agricultural area and yield as baseline for the analysis	+ Transition to 100% organic production[1]	+ Incorporate proven technologies	+ Shift production towards plant-based protein	Limit production to align with planetary boundaries
Farm type:	Conventional	Organic	Organic	Organic	+ Organic
Innovation:	Current state	Current state	Innovative	Innovative	Innovative
Protein production:	60% animal – 40% plant	43% animal – 57% plant	39% animal – 61% plant	30% animal – 70% plant	30% animal – 70% plant
Production area:	1.80 m ha	1.80 m ha	1.80 m ha	1.80 m ha	0.95 m ha

[1] We use organic agriculture as a proxy to quantify farm systems that have lower environmental impacts. More information on this decision is here.

Alternative 1

Low-impact farming

Alternative 1 | Low-impact farming

In the first alternative, primary production in the Netherlands transitions to low-impact farming methods.

We have used 100% organic production as a proxy for farming with low environmental impacts.

Organic farming is currently more widely implemented than other emerging low-impact practices such as regenerative, circular and nature-inclusive agriculture. This means that comprehensive data was available for our analysis. Furthermore, established European standards for organic farming provide clear definitions, and enable comparability and robust assessments of economic and environmental impacts.

Organic farming has both benefits and drawbacks

Transitioning to organic agriculture brings benefits including improved soil health, increased biodiversity, reduced use of synthetic chemicals and pesticides, and enhanced animal welfare. That said, it can also be labour-intensive and may produce lower yields than conventional farming.

Radical transition as a first step to transformation

Achieving 100% organic farming may seem aspirational. It currently accounts for only around 5% of the Netherlands' total agricultural area (CLO, 2025) and the government's policy target is only 15% by 2030. The transition would also offer significant challenges with regards to lower output per hectare, land required for feed production, farmer business cases and consumer prices.

However, by modelling the 100% organic alternative, we demonstrate that radical implementation of lower-impact farming practices would significantly reduce the societal costs of agriculture.

Key assumptions used in calculations
(more information here):

- The agricultural area of the Netherlands stays the same.
- Organic farming produces lower yields than conventional farming by an average of -45% for livestock, -15% for horticulture and -25% for arable.
- Prices for organic products are 23-30% higher and partially mitigate reduced revenue from lower yields.
- Export volumes reduce due to lower production levels and higher prices.
- Pesticide use reduces by 92%.
- Chemical fertiliser use reduces by 100%.
- Livestock feed, including imports, adheres to organic standards and is priced 25% higher than conventional feed. However, the amount used reduces by 40%, resulting in a 24% cost reduction for concentrate feed.
- Additional mechanical weed control in organic farming increases energy use by 10% over conventional farming.
- Protein and energy per kilogram is equal in both conventional and organic products.

Organic definitions used in the analysis

Organic farming	Definition	Source
Plant-based organic farming practices	Organic farmers, gardeners and growers: • protect their crops as naturally as possible against weeds, diseases and insect pests; • primarily use organic manure and compost in the fields and greenhouses; • cultivate multiple types of crops and rotate them annually (crop rotation); • allow most vegetables to grow in open soil (not in pots or containers), even in greenhouses; • do not use genetic modification.	LVVN, 2025
Animal-based organic farming practices	For animal-based organic products, the following applies: • animals have more space in the stable and always have access to outdoor air or pasture, unless the weather, ground conditions or illness prevent it; • animal feed is also organic; • farmers use limited antibiotics and prioritise natural remedies for sick animals where possible; • more natural animal behaviour is facilitated.	LVVN, 2025

Low-impact farming | Results

Transitioning to 100% organic **reduces net negative impact to -€1.0 billion**. It significantly cuts societal costs, but would also reduce production levels.

Economic benefits

Economic value added is 25% lower with 100% organic farming than with current agricultural practices.

Value added through primary production

€ 10.0 billion

↓ €3.3 billion vs current system

Farmer revenue

↓27%

vs current system

- Lower yields reduce revenues for farmers
- Higher prices for organic products partially mitigate the revenue loss
- The cost of production inputs decreases due to changes in use of livestock feed, fertilisers and pesticides
- Energy costs increase slightly.

[1] Revenue and costs methodology

Societal costs

However, organic farming cuts costs to society by 41% through reduced environmental impacts.

Societal costs

€ 11.0 billion

↓ €7.5 billion vs current system

Societal costs per environmental impact for this alternative (€bn)

Climate change	-€ 5.4
Phosphorus	-€ 0.1
Nitrogen (Incl. ammonia)	-€ 4.3
Water consumption	-€ 0.04
Land use and biodiversity loss	-€ 1.4
Particulate matter	-€ 0.2
Pesticides	-€ 0.03
Soil health	+ € 0.5 (positive impact)

Nutritional value

Protein and energy production both reduce significantly due to yield reductions

Protein production

1.1 billion kg

Protein production ↓ 41% vs current system
Energy production ↓ 34% vs current system

45% drop in yield from livestock farming results in an implicit shift towards plant-based protein.

43% **Animal-based** ↓17% from current system

57% **Plant-based** ↑17% from current system

Total kcal production could feed the Dutch population 1.7 times

Low-impact farming | Observations and considerations

Costs to society are reduced, but so are economic benefits and nutritional value

Economic benefits are reduced

Product prices rise, but yields decrease. This leads to an overall reduction in total economic added value.

Shifting to organic farming reduces farmers' revenues due to lower yields. However, input costs also reduce through minimal use of pesticides and chemical fertilisers, and lower reliance on feed concentrates.

Considerations

- Shifting to 100% organic agriculture requires substantial initial investments by farmers. This analysis does not include these transition costs.
- Farmers may benefit from higher market prices for organic products, provided the market is willing and able to absorb them. However, higher prices may reduce consumer affordability and demand.
- Reducing overall production would decrease export surpluses, which would negatively affect national income from agriculture.
- Lower production not only reduces farmer revenue, but also negatively impacts the broader agricultural value chain and related GDP. For example, downstream economic activities such as processing, transport and trade would also be affected.

Societal costs are reduced

Organic practices lower the risk of exposing farmers and consumers to harmful chemicals by almost eliminating the use of chemical pesticides and fertilisers. They also reduce the societal costs of biodiversity loss by 42% compared with the current agricultural system.

Enhancing soil quality boosts carbon sequestration and water retention. The climate impact of agriculture is also significantly lower than in the current system (-32%). This is largely because organic farming requires more space per animal, resulting in fewer animals on the same land.

Considerations

- The use of organic fertilisers, if not properly managed, may still lead to nutrient run-off and water quality concerns.
- Organic farming is not entirely free of GHG emissions. For example, it continues to generate emissions through transport, distribution and cooling.
- Lower domestic production would reduce export volumes, which could shift environmental pressures to other countries.

Protein and energy production is reduced

A full transition to organic farming would significantly reduce the amount of protein and energy produced. Nevertheless, production would continue to exceed the Dutch population's caloric energy needs.

Organic transition would also shift production towards plant-based proteins. This is because organic methods require more space per animal, leading to a drop in the amount of animal protein produced.

Organic methods would also reduce yields in greenhouse horticulture and arable farming, but by lesser amounts than in livestock farming.

Considerations

- The decrease in surplus protein and calorie production reduces the country's buffers for domestic markets and its capacity to export food.
- Lower output may limit flexibility to respond to disruptions such as poor harvests, trade interruptions or demand spikes. This analysis does not quantify these risks.
- Improved soil health in organic agriculture may improve the nutritional value of food produced and support a healthier population (Feliziani et al., 2025). This analysis does not quantify these benefits.

Alternative 2

Smart innovation

Alternative 2 | Smart innovation

Introducing technological advancements in farming practices and machinery could further increase the benefits of low-impact farming practices.

Innovations to improve environmental impacts and reduce societal costs

Innovative practices that could be incorporated into organic farming include:

- **Electrifying agricultural vehicles:** transitioning from fossil fuel-powered machines to electric agricultural vehicles and equipment.
- **Using sustainable energy:** increasing the use of solar, wind and biogas energy in agricultural operations.
- **Implementing smart irrigation systems:** applying systems such as drip irrigation and water recovery.
- **Increasing precision in agriculture:** using technologies such as GPS, sensors, ICT and robotics to monitor plants and animals and reduce waste.
- **Developing circular agriculture:** using by-products from one activity as inputs for another. For example, increasing the use of compost or manure, or using residual nutrients and organic matter from other crops to enhance soil fertility and reduce waste.
- **Increasing intercropping:** reducing monocultures by cultivating multiple crops simultaneously in the same fields. This optimises the use of resources and ecological processes.

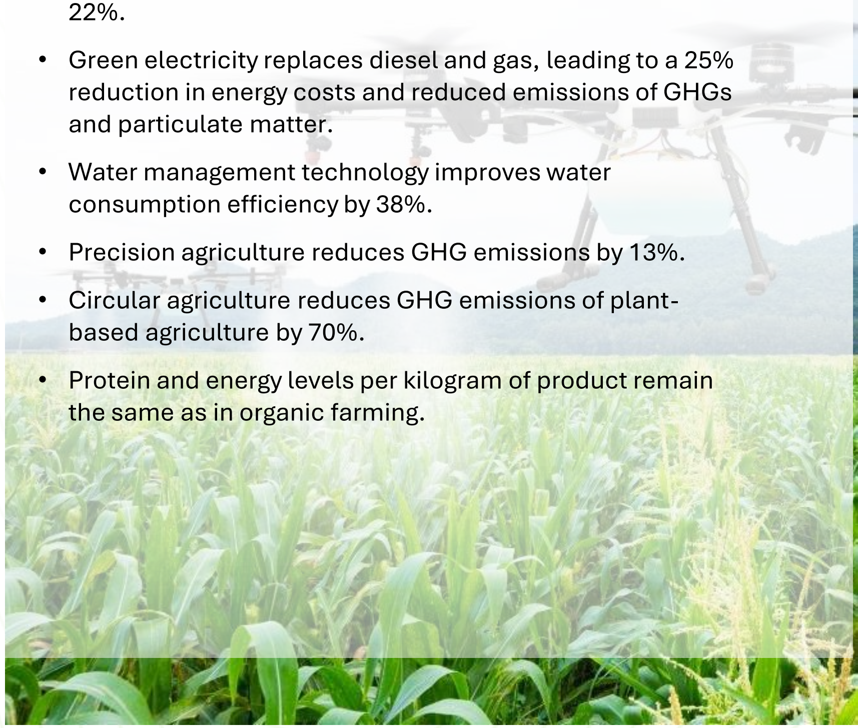
Innovation or reintroduction?

Not all the practices assessed are new; most are already proven however not always on such a large-scale. Circular farming and intercropping, for example, are traditional methods. They have largely fallen out of use in the modern system which favours intensive monoculture farming.

Reintroducing traditional methods could help to overcome the yield gap between organic and conventional farming practices while promoting ecosystem health.

Key assumptions in calculations
(more information here):

- The agricultural area of the Netherlands stays the same.
- The analysis is based on the introduction of smart innovation incremental to existing innovation in Dutch agriculture.
- Intercropping increases yields of vegetables, grains and other arable produce (except potatoes and fresh fruit) by 22%.
- Green electricity replaces diesel and gas, leading to a 25% reduction in energy costs and reduced emissions of GHGs and particulate matter.
- Water management technology improves water consumption efficiency by 38%.
- Precision agriculture reduces GHG emissions by 13%.
- Circular agriculture reduces GHG emissions of plant-based agriculture by 70%.
- Protein and energy levels per kilogram of product remain the same as in organic farming.



Smart innovation | Results

Smart innovation, combined with 100% organic farming, could increase yields and further reduce environmental impacts, **resulting in a net positive impact of + €2.7 billion.**

Economic benefits

Smart innovation could increase organic farming yields of some crops by around 22%, adding €1.7bn in economic value. However, the overall economic value added would still be 12% lower than the current system.

Value added through primary production

€ 11.7 billion

↓€1.6bn vs current system

Farmer revenue

↓23%

vs current system

- Better land use increases yields.
- Replacing gas and diesel with electrification, reduces operational costs.
- Together these innovations improve the economic value add of farmers by 17% from 100% organic farming.

[1] Revenue and costs methodology

Societal costs

Smart innovation and organic farming together could reduce the current societal costs of farming by more than half (- 52%).

Societal costs

€ 9.0 billion

↓ €9.6 billion vs current system

Societal costs per environmental impact for this alternative (€bn)

Climate change	-€ 3.5
Phosphorus	-€ 0.1
Nitrogen (Incl. ammonia)	-€ 4.2
Water consumption	-€ 0.04
Land use and biodiversity loss	-€ 1.4
Particulate matter	-€ 0.2
Pesticides	-€ 0.03
Soil health	+ € 0.5 (positive impact)

Nutritional value

Introducing smart innovation could increase the protein and energy production of 100% organic farming by around 10%. However, production would remain lower than in the current agricultural system.

Protein production in the Netherlands

1.2 billion kg

Protein production ↓ 35% vs current system
Energy production ↓ 26% vs current system

Smart innovation could increase average yields from horticulture and arable farming significantly, further accelerating a shift towards plant-based protein. Yields from livestock farming would remain similar to organic farming.

39% Animal-based
↓21% from current system

61% Plant-based
↑21% from current system

Total kcal production could feed the Dutch population 1.8 times

Smart innovation | Observations and considerations

Introducing smart innovation increases plant-based yields and protein production, while significantly reducing societal costs

Plant-based yields increase

Smart innovation - primarily intercropping - significantly increases the plant-based yields of 100% organic farming. Intercropping optimises land use and uses natural resources more efficiently. This increases production from the same land area.

Electrifying farm vehicles and greenhouse heating systems not only lowers operational costs, but also makes production more energy-efficient.

Considerations

- Introducing smart innovation alongside organic practices requires significant investment in **new practices, technology and training**. The analysis does not include these transition costs.
- These transition costs could **increase production costs in the short-term** and temporarily increase prices for consumers. However, in the **longer-term**, prices could also decrease due to smart innovation efficiencies.
- By increasing productivity, smart innovation could **strengthen the Netherlands' export position** and **sectoral competitiveness** compared with organic farming alone.
- Technology providers and service companies would benefit from increased demand for innovation. **New markets could be created** for precision agriculture equipment, digital farm management tools, sensors and automation.

Societal costs are significantly reduced

Smart innovation, alongside organic farming, could dramatically reduce the current agricultural system's costs to society. Practices such as precision nutrient management and advanced manure processing could reduce the negative environmental impacts of water consumption by 10% and of nitrogen emissions by 14%.

Fewer livestock, and improved soil management that increases carbon capture, could reduce GHG emissions by more than one-third (35%) compared with organic farming alone.

Considerations

- Livestock emissions, particularly **methane** and **nitrogen**, will continue to be a challenge.
- **Careful assessment** of smart innovation value chains is needed, to guard against hidden impacts such as increased emissions or resource consumption.

Plant-based protein production increases

Introducing smart innovation to organic farming could increase the plant-based share of overall protein production by a further 4%. This is mainly due to higher crop yields.

Total protein and energy production remains robust, helping to safeguard national food security despite lower production of animal protein. The system still delivers almost twice the kilocalories required to feed the Dutch population.

Considerations

- **Greater diversity and resilience** of production methods enhances the stability of the national food supply.
- **Careful monitoring** would be needed to ensure that ongoing evolution of the system continues to provide Dutch people with adequate variety and nutrition.

Alternative 3

Protein shift

Alternative 3 | Protein shift

Alternative 3 is based on reallocating 18.5% of land used for raising livestock to crop production.

This would shift Dutch protein production from 61% (in alternative 2) to 70% plant-based and from 39% to 30% animal protein. The ratio reflects a diet proposed by the EAT-Lancet commission of 65 - 70% plant-based, in which dietary protein comes mainly from grains, root crops, legumes, nuts and seeds (Willett et al., 2019).

A significant shift towards plant-based protein would align with growing public awareness of animal agriculture's negative environmental impacts.

Increasing plant-based protein production would deliver not only environmental benefits, but also public health advantages. These include lower risks of chronic diseases such as cardiovascular conditions, diabetes and certain cancers (e.g. Lacour et al., 2018, Lynch et al., 2018, Key et al., 2022).

Focusing on production rather than consumption patterns

This model is based on a production, rather than a consumption, ratio, and thus represents a proactive approach to transforming agriculture. Focusing on consumption patterns can overlook the environmental impacts of food production.

Building on protein shifts in organic farming and smart innovation

In today's Dutch agricultural system, approximately 40% of protein produced is plant-based. This excludes plant-based products used as animal feed.

In a total transition to organic farming (Alternative 1 of this analysis), the share of plant-based protein would increase to 57%, due to a reduction in livestock yields.

Introducing smart innovation, as in Alternative 2, would increase the share of plant-based proteins to 61% of protein production.

The change of land use explored in Alternative 3 to achieve 70% plant-based protein production therefore builds on a shift that began in the two previous alternatives.

[1] Derived bottom-up at production volume level, not via top-down consumption estimate

Key assumptions in calculations
(more information here):

- The agricultural area of the Netherlands stays the same.
- 18.5% of land previously used for animal agriculture is reallocated to crop production.
- Land reallocated to crop production is used for crops already grown in the Netherlands; novel or harder-to-grow high-protein crops are not introduced.
- Crops are grown on the reallocated land in the same proportions as current Dutch arable and horticultural production.
- The model assumes existing Dutch soil and climate conditions can support increased cultivation of crops.
- Protein and energy per kilogram of product remain the same as in the current system.

Protein shift | Results

The protein shift increases economic benefits close to the level of the current agricultural system, **resulting in a net positive impact of + €5.3 billion.**

Economic benefits

Shifting the protein production ratio, on top of transitioning to organic farming and introducing smart innovation, could create economic value almost equal to the current system.

Value added through primary production

€ 13.2 billion

↓€0.1 bn vs current system

Farmer revenue

↓21%

vs current system

Farmers' revenues are higher than in the previous alternatives, but still significantly lower than in the current system. However, reallocating livestock land to crop production also lowers costs significantly, for example the cost of animal feed. As a result, the overall economic value add is almost on a par with the current system.

[1] Revenue and costs methodology

Societal costs

Costs to society would be 58% lower than in the current agricultural system.

Societal costs

€ 7.9 billion

↓ €10.6 billion vs current system

Societal costs per environmental impact for this alternative (€bn)

Climate change	-€ 2.9
Phosphorus	-€ 0.1
Nitrogen (inc. ammonia)	-€ 3.6
Water consumption	-€ 0.03
Land use and biodiversity loss	-€ 1.5
Particulate matter	-€ 0.2
Pesticides	-€ 0.03
Soil health	+ € 0.5 (positive impact)

Nutritional value

Reallocating livestock land to crop production, would increase the amount of protein and energy produced by organic farming with smart innovation by around 8%.

Protein production in the Netherlands

1.3 billion kg

Protein production ↓ 26% vs current system
Energy production ↓ 1% vs current system

30% **Animal-based**

↓30% from current system

70% **Plant-based**

↑30% from current system

Total kcal production could feed the Dutch population 2.2 times
(Up from the 1.8 times of organic farming with smart innovation)

Protein shift | Observations and considerations

Switching to 70% plant-based protein production, together with organic farming and smart innovation, cuts the current societal cost of agriculture by more than half

Economic value is increased

The protein shift, in addition to organic transition and smart innovation, increases the economic added value of Dutch agriculture to €13.2 billion. This is almost on par with the economic value of the current system (€13.3 billion).

Farmers' revenue increases from the previous two alternatives due to increase in food production, but remains lower than in the current system. The loss of revenue is largely offset by a corresponding drop in costs, mainly animal feed.

Considerations

- Converting farmland from livestock to crop production, and adjusting farming methods, would require **capital investment**. This analysis does not include these transition costs.
- Demand for animal feed would be more than halved from current levels, reducing Dutch dependence on **imported feed** and improving **land-use efficiency**.
- Shifting to more plant-based protein production would challenge the **traditional economic role** of the Dutch livestock and dairy sectors. For example, in this alternative, total raw milk production drops 51% compared with the current system.
- The protein shift could create opportunities to develop innovative, high-quality plant-based products and build **new export markets**.

Societal costs are reduced

The protein shift can reduce ammonia pollution by a further 19% and GHGs by a further 17% from the levels achieved through organic farming with smart innovation.

Conversely, it could increase negative environmental impacts associated with nitrogen, phosphorus and biodiversity loss. These impacts are typically higher in crop production than in livestock farming.

Despite this, total societal costs are 57% lower than in the current system.

Considerations

- This calculation of societal costs does not include the potential public health benefits of shifting diets towards plant-based protein.

Protein production increases from previous alternative

The shift to 70% plant-based protein production would slightly increase the amount of protein produced by organic farming with smart innovation.

However, total protein production would remain significantly lower than in the current agricultural system (1.3bn vs 1.8bn kg).

Considerations

- **Consumer education** would be important to promote acceptance of plant-based dietary alternatives.
- The shift in production from animal- to plant-based protein would require a clear strategy to maintain a competitive position for Dutch producers in export markets.

Alternative 4

Reduced production scenario

Alternative 4 | Reduced production scenario

Research suggests that our agricultural system needs to operate within planetary boundaries if it is to be resilient in the long term.

As long as it exceeds planetary boundaries, it remains vulnerable to environmental, social and economic disruptions and is putting food security, economic stability and a healthy living environment at risk.

The first three alternatives in this report (low-impact farming, smart innovation and the protein shift) would significantly reduce the societal costs of agriculture. However, Dutch food production would continue to exceed some planetary boundaries, even with these alternatives in place. In particular, agriculture’s GHG emissions would still exceed planetary boundaries (90% above the threshold).

Reduced production could bring the system within planetary boundaries

Reducing overall primary production, or shifting even further towards plant-based protein, are the two main options to bring Dutch farming within planetary boundaries.

In this analysis we find that keeping within planetary boundaries would require the first three alternative systems to be implemented at 100% and the land area used for primary production to be reduced by almost half (-47%) from 1.80 m hectares to 0.95 m hectares, on top

Lower production has massive economic implications

Transitioning to an agricultural system with significantly lower production would clearly impact the Netherlands' export capacity and GDP, employment and consumer prices. Therefore, we consider it a rather hypothetical scenario in the mid-term, providing direction rather than a realistic alternative for now.

Limitations of the planetary boundaries

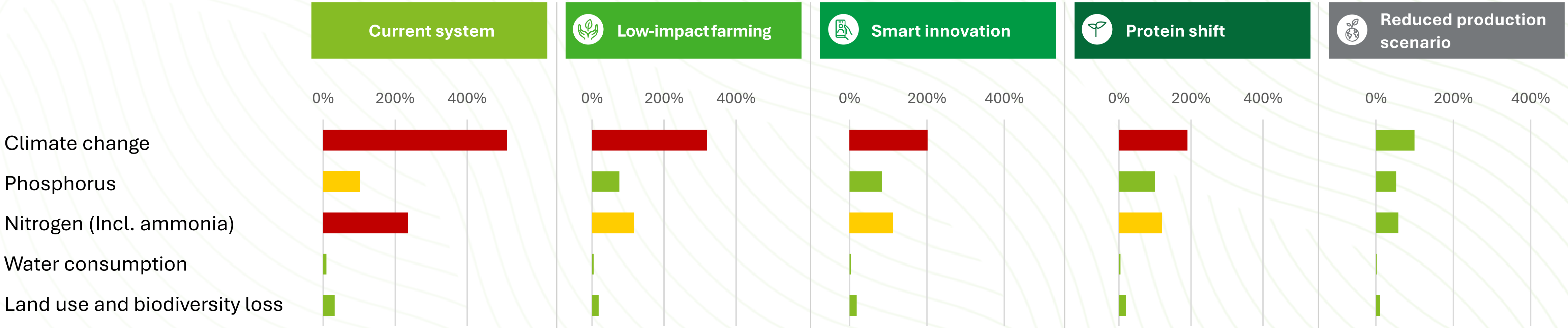
While the planetary boundaries framework provides valuable guidance by focusing on five key earth systems—climate change, land use, water use, nitrogen and phosphorus cycles—it does not capture all environmental impacts or societal costs. Other important issues, such as soil degradation, and broader social consequences, also affect resilience but fall outside the scope of these boundaries. As a result, meeting planetary boundaries alone does not guarantee the absence of wider environmental or societal challenges.

Key assumptions in calculations
(more information here):

- Area used for primary agricultural production reduces by 47%.
- The reduction in production is applied proportionally across all crop and livestock categories to maintain the same plant-to-animal protein ratio as in Alternative 3.
- Protein and energy per kilogram of product remain the same as in the current system.

Reduced production scenario | Planetary boundary analysis

For the agricultural system to operate within its planetary boundaries, production needs to be almost halved after implementing the first three alternative systems



- *Within boundary*
- *Crossing boundary*
- *Far beyond boundary*

Current system
- The current system exceeds three of the five boundaries

Low-impact farming
- Low-impact farming brings phosphorus into the boundary

Smart innovation
- Smart innovation lowers GHG, however still not enough to be in the safe space

Protein shift
- Nitrogen and GHG boundary remain limiting factors with protein shift to 70% plant-based production

Reduced production scenario
- Keeping within these five planetary boundaries requires primary production to be reduced by almost half from alternative 3

The boundaries used for this analysis have been specifically defined for global food production by the EAT-Lancet commission (Willett et al., 2019) and were attributed to the Dutch sector. More information about our attribution method is provided here.

Reduced production scenario | Results

The Dutch agricultural system could operate within planetary boundaries by significantly reducing production. A **net positive impact of + €5.3 billion could be achieved:** equal to Alternative 3 (Protein Shift).

Economic benefits

Economic value added would be 31% less than the current system.

Value added through primary production

€9.2 billion

↓€4.1 bn vs current system

...

Farmer revenue

↓58%

vs current system

Reduced production would lower both revenues and operating costs for Dutch farmers.

[1] Revenue and costs methodology

Societal costs

Costs to society would be reduced by 79% compared with the current system.

Societal costs

€ 3.9 billion

↓€14.6 billion vs current system

Societal costs per environmental impact for this alternative (€bn)

Climate change	-€ 1.5
Phosphorus	-€ 0.1
Nitrogen (Incl. ammonia)	-€ 1.9
Water consumption	-€ 0.02
Land use and biodiversity loss	-€ 0.8
Particulate matter	-€ 0.1
Pesticides	-€ 0.02
Soil health	+€ 0.5 (positive impact)

Nutritional value

The agricultural system would continue to meet the protein and energy needs of the Dutch population, despite significantly reduced production.

Protein production in the Netherlands

0.7 billion kg

Protein production ↓ 61% vs current system
Energy production ↓ 53% vs current system

...

The production ratio of animal and plant-based protein remains the same as in Alternative 3 (Protein Shift) because production is reduced equally across the sector.

...

30% Animal-based

70% Plant-based

...

Total kcal production could feed the Dutch population 1.2 times

Reduced production scenario | Observations and considerations

Operating within planetary boundaries would greatly reduce societal costs, but also economic benefits and nutritional value

Both revenues and costs decrease for farmers

Reducing production results in a substantial decrease in both revenue and operating costs for Dutch farmers.

This reduces financial returns and affects the sector's contribution to national GDP and exports.

The economic focus would need to shift from volume growth to profitability within environmental limits

Considerations

- Lower production would also **reduce employment** within the sector.
- Maintaining economic viability would require **new business models** focused on quality, sustainability and local or regional markets.
- Policymakers would need to provide substantial **transition support** and tailored policies to help farmers and rural communities adjust.
- Lower domestic production would **raise food prices,** but the effect may be limited because prices are largely determined by global and European markets.

Societal costs are significantly reduced

The 79% reduction in societal costs results from cleaner water, improved air quality, healthier soils and improved conditions for biodiversity.

All major environmental indicators (GHG emissions, nitrogen, phosphorus, water use and land use) now fall within recognised planetary boundaries.

Environmental impacts reduce drastically, primarily due to fewer livestock and less intensive farming. For example, GHG emissions fall by 80%, nitrogen and ammonia by 73%, and water consumption by 75% compared with the current system.

Considerations

- The growing global population means keeping the agricultural system within planetary boundaries would be an **ongoing challenge.** Boundaries are set on a per capita basis, meaning that as the population expands the environmental impact of each person needs to reduce. Remaining within the boundaries would therefore require continuous **improvement, monitoring** and **adaptation** of farming practices.

Protein and energy production reduces

The Netherlands still meets its domestic needs, but its ability to export large surpluses is greatly reduced. The diversity of food products and the availability of specific nutrients, e.g., vitamin B12, may also drop, as there will be less food available to process into other food types, e.g. cheese.

Considerations

- Long-term planning would be needed to protect **national food security**, ensuring sufficient food reserves in the absence of large surpluses.
- **Strategic optimisation of land use** – for example, further prioritisation of crops over milk production – may be needed. This could influence both the variety of production and market dynamics.

Conclusion

Summary | From net negative to net positive

Transitioning to a smarter, lower-impact agricultural system can shift the current balance from net negative to net positive. However, this will require deliberate, well-sequenced policy reform and targeted investments

This study compares the economic benefits and societal costs of the current Dutch agricultural system with a cumulative series of four alternative systems. By putting a monetary value on both economic benefits and societal costs, we gain holistic insight into the true impacts of agriculture. We can understand where today's system succeeds, and where its costs to society have implications for long-term prosperity.

The status quo: High returns, higher societal costs - € 5.3 bn

Dutch agriculture sets a global productivity benchmark, yet our analysis shows that its contribution to GDP is outweighed by the societal costs it imposes. In particular, its emissions of GHGs and nitrogen (including ammonia) and its land use impacts on biodiversity —driven largely by dairy, beef and pork production — help to create a net negative impact.

Alternative 1: Low-impact farming - € 1.0 bn

Converting all production to methods with lower environmental impacts, for which we use organic as a proxy, would lower environmental impacts, restore soil function and increase on-farm biodiversity. The transition to 100% organic would be a large step-up from currently ~5% of land use and offer significant challenges with regards to lower output per hectare, land availability for feed production, farmer business cases and consumer prices.

Alternative 2: Low-impact farming with smart innovation + € 2.7 bn

Introducing precision technologies, electrified equipment and advanced water management tools into a fully organic system reduces the yield losses. Our model suggests that innovation can absorb part of the productivity penalty while materially reducing emissions and water withdrawal.

Alternative 3: Protein shift + € 5.3 bn

Re-orienting production towards 70 percent plant protein and 30 percent animal protein lifts total protein output and slashes ammonia and GHG emissions. Some pressures—such as nutrient run-off and certain land use impacts—could intensify if not carefully managed, but the overall costs to society drop markedly.

Scenario: Reduced production (Alternative 4) + € 5.3 bn

Enabling the system to operate within its planetary boundaries would require production to be capped at levels consistent with the Netherlands' share of global ecological limits. This, in the mid-term rather hypothetical, scenario would deliver the steepest reduction in environmental impacts and related societal costs.

Protein output would fall by around 60 percent relative to today, and economic value added would reduce accordingly. However, GHG emissions, nutrient surpluses and habitat pressures all would retreat into a genuinely sustainable range. Of all the alternative systems analysed, it would offer the clearest path to long-term ecological resilience.

The implementation of the alternative systems at full would come with significant challenges. The modelling thereof should rather give direction and serve as a touchstone for future decisions.

Implications

Taken together, the results demonstrate that:

- Meaningful reductions in societal costs are achievable without sacrificing food security, provided the system shifts towards low-input practices, technology-enabled efficiency and a decisive plant-protein focus.
- While incremental measures can deliver significant improvements in environmental impacts and related societal costs, they are insufficient to bring the system entirely within its ecological limits. Doing so would ultimately require a smaller, smarter and more diversified agricultural footprint.
- The transition to an agriculture system within planetary boundaries would come with significant disruption to the sector's earning potential and related employment, farmer economics, and consumer prices and consumption shifts, if not carefully managed.
- On the positive side, the transition inhibits opportunities for the Dutch agri sector to become a front-runner in high-value, low-impact food and agtech sectors.
- To navigate the challenges and opportunities, the transition demands a deliberate and well-sequenced combination of policy reform, targeted investments, market incentives, and close collaboration across the value chain by key stakeholders.

Comparison | Summary of key changes

Implementing the first three alternative systems – low-impact farming, smart innovation and the protein shift – would have the following effects vs the current system:

Economic benefits

- **Economic value added by primary production remains steady**
- **Cost of imported animal feed drops by ↓55%**
- **Imports of chemical fertilisers and pesticides are almost eliminated** along with the associated cost
- **Export value drops by ↓21%**
- **Consumer prices may rise short-term but decline as volume efficiencies materialise, and fall faster with sufficient government support.**

Societal costs

- **Societal costs of environmental impacts fall as follows:**
  - Climate change ↓63%
  - Phosphorus ↓3%
  - Nitrogen to water ↓21%
  - Nitrogen to air (ammonia) ↓55%
  - Water consumption ↓53%
  - Land use adjusted for biodiversity loss ↓41%
  - Particulate matter ↓57%
  - Pesticides ↓92%
  - Soil health improves

Nutritional value

- Animal protein production drops by ↓63%
- Plant protein production increases by ↑30%
- Total protein production drops by ↓26%

Zoom in | How alternative systems change key impacts

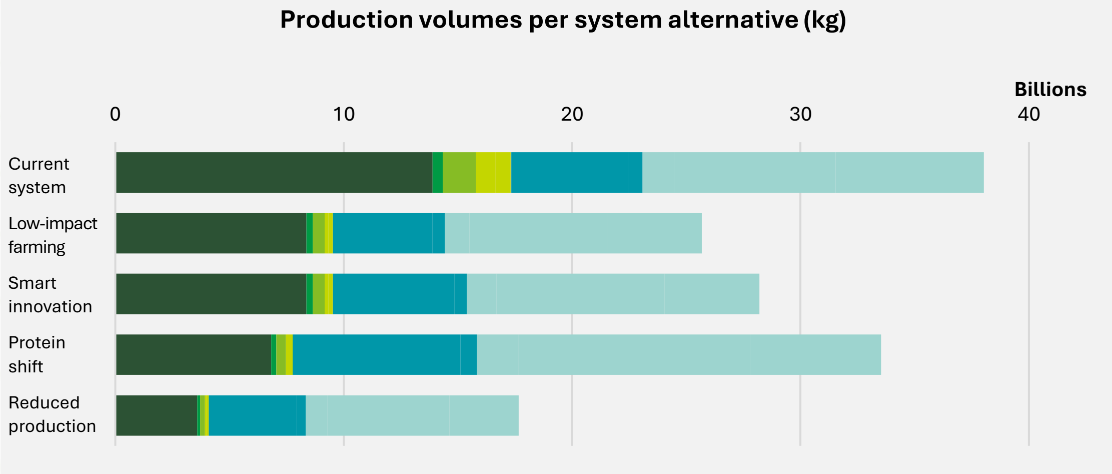
		Current system *Status quo*	Alternative 1 *Low –impact farming*	Alternative 2 *Smart innovation*	Alternative 3 *Protein shift*	Alternative 4 *Reduced production*
Economic benefits and costs (€ bn/yr)	**Added economic value through primary production**	13.3	10.0	11.7	13.2	9.2
	Import of animal feed (cost)	- 3.7	- 2.1	- 2.1	- 1.7	- 0.9
	Import of fertilisers (cost)	- 0.7	0.0	0.0	0.0	0.0
	Import of pesticides (cost)	- 0.6	0.0	0.0	0.0	0.0
	Export of agricultural products from Dutch production (benefit)	83.4	60.8	64.0	66.0	34.7
Societal costs (€ bn/yr)	Climate change	- 7.9	- 5.4	- 3.5	- 2.9	- 1.5
	Phosphorus	- 0.1	- 0.1	- 0.1	- 0.1	- 0.1
	Nitrogen to water	- 1.3	- 1.1	- 0.9	- 1.0	- 0.5
	Nitrogen to air (ammonia)	- 5.8	- 3.2	- 3.2	- 2.6	- 1.4
	Water consumption	- 0.1	- 0.04	- 0.04	- 0.03	- 0.02
	Land use adjusted for biodiversity loss	- 2.5	- 1.4	- 1.4	- 1.5	- 0.8
	Particulate matter	- 0.5	- 0.2	- 0.2	- 0.2	- 0.1
	Pesticides	- 0.4	- 0.03	- 0.03	- 0.03	- 0.02
	Soil health	0.0	0.5	0.5	0.5	0.2
	Total societal costs	- 18.6	- 11.0	- 9.0	- 7.9	- 3.9
Nutritional value	Total animal-based protein (kton)	1,090	496	496	404	213
	Total plant-based protein (kton)	713	567	674	930	489
	Total protein production (kton)	1,804	1,063	1,170	1,334	702
	Social costs per kton protein (mln €/kton)	10.3	10.3	7.7	5.9	5.6
	Energy (kcal) produced compared with needs of Dutch population	2.5	1.7	1.8	2.2	1.2
Net added value (€ bn/yr)	**Added economic value minus societal costs**	- € 5.3	- € 1.0	€ 2.7	€ 5.3	€ 5.3

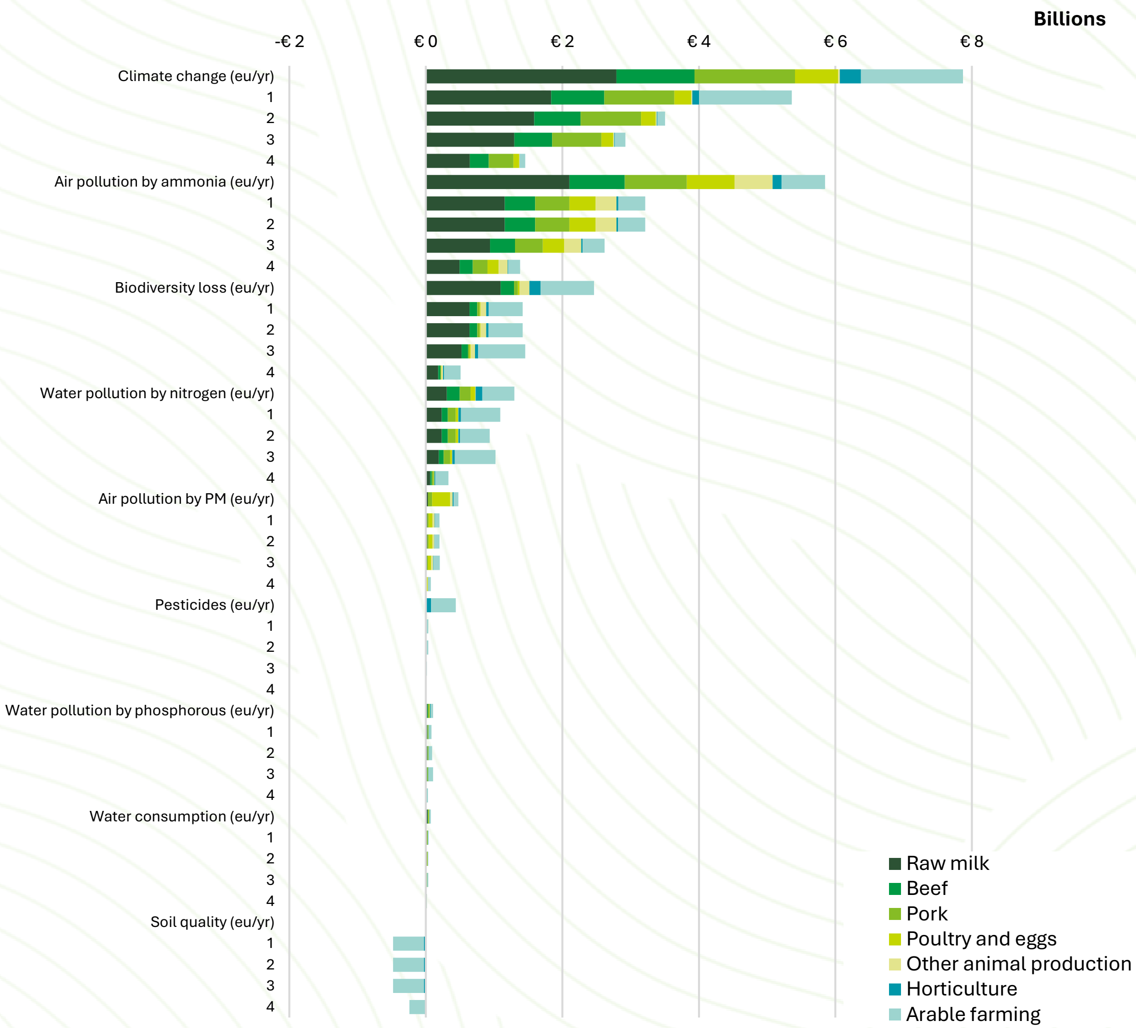
Black = equal to previous alternative **Red = worse than previous alternative** **Green = better than previous alternative**

Comparison | How alternative systems affect societal costs and production volumes

Our analysis indicates that:

- **Climate change**, air pollution from **ammonia**, and **biodiversity loss** are the primary drivers of societal costs across all agricultural alternatives.
- Traditional animal production methods, especially **raw milk, beef,** and **pork**, are major contributors to these societal costs.
- **Plant-based foods** generally impose lower societal costs, but intensive arable farming and large-scale production of certain crops (e.g. onions, sugarbeet) can also create environmental challenges.
- **Organic farming**, as a proxy for lower-impact farming methods, can help to reduce the societal costs of Dutch agriculture significantly. However, it would lead to a decrease in production volumes, especially for milk.
- Introducing **smart innovation** can mitigate negative impacts by reducing GHG and ammonia emissions, while increasing yields. Increasing the share of **plant-based production** can further reduce societal costs and increase yields, underlining the environmental benefits of plant-centric diets.





Comparison | How alternative systems perform against planetary boundaries

Alternative systems can improve performance, but operating within planetary boundaries requires significantly reduced production.

Introducing low-impact farming, smart innovation and a protein shift would take the agricultural system significantly closer towards operating within its planetary boundaries.

However, a reduction of almost 50% in production would be required to enable the system to operate entirely within the boundaries. This is primarily due to especially high GHG and nitrogen emissions from Dutch agriculture. For two planetary boundaries (water use and land use adjusted for biodiversity), the Dutch agricultural system operates already within the planetary boundaries.

Attributing planetary boundaries to Dutch agriculture

The planetary boundary approach offers valuable insights, but it is not an exact science. Currently, there are no defined planetary boundaries for the Netherlands, although there is progress in this area. As a result, we have adopted a pragmatic approach of allocating global boundaries to the Netherlands based on population size. This enables a comparative assessment of the environmental impacts associated with each alternative, despite the inherent limitations of the model.

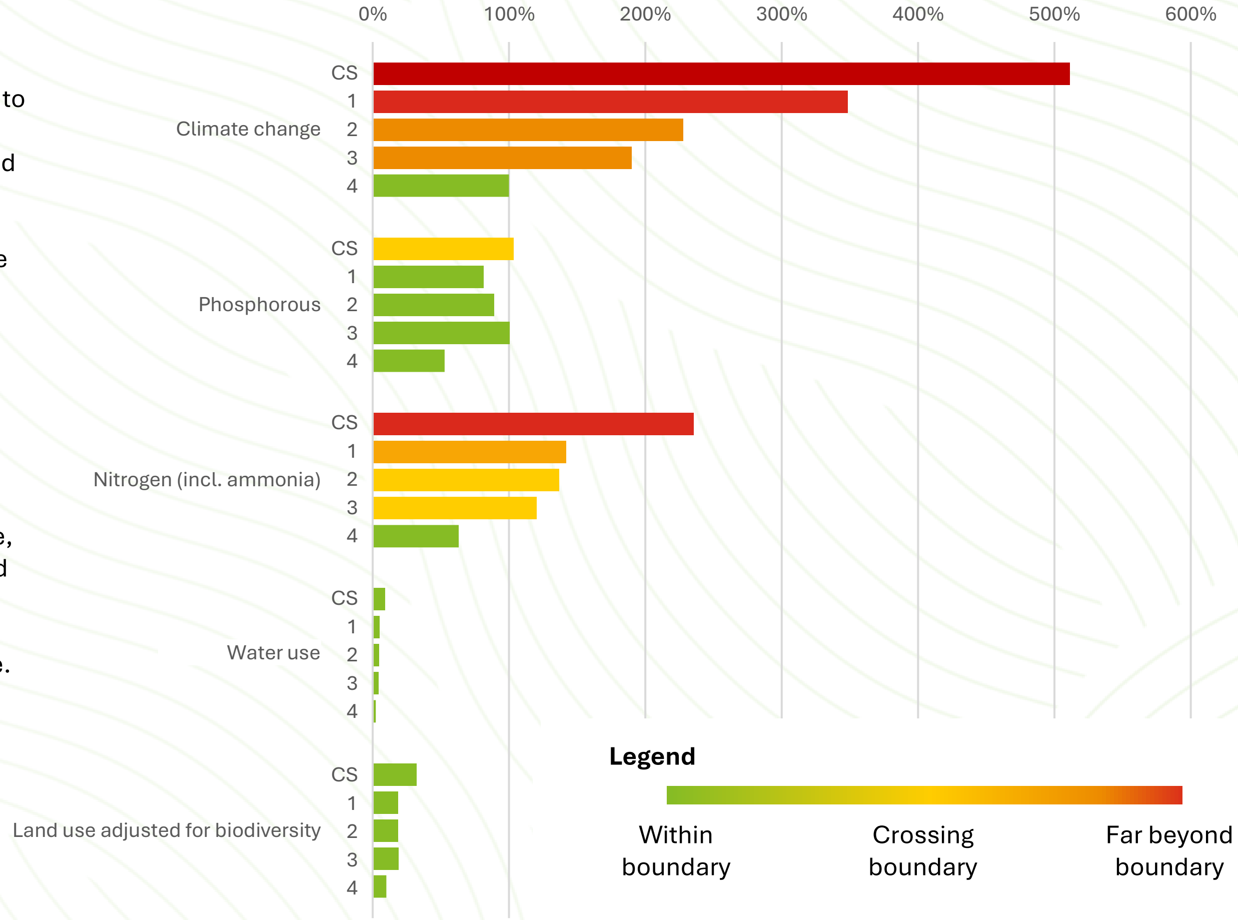
Limitations to the application of planetary boundaries using LCA data

The use of life cycle assessment (LCA) data leads to significantly inflated impact figures compared to the actual figures related solely to the Dutch food system. For instance, greenhouse gas emissions from imported feed are also included in the assessments. Furthermore, nitrogen emissions have been adjusted to include ammonia, since these are significant in the Netherlands.

Why are planetary boundaries important in agriculture?

If a system consistently exceeds its environmental limits, it risks collapse. Our analysis focuses on specific boundaries, but does not fully capture the systemic interconnections between them. For example, water scarcity driven by climate change could make agriculture unviable. In this context, healthy soil that can store water becomes critical to safeguarding agricultural resilience.

Performance of alternative agricultural systems against planetary boundaries



Conclusion | Key challenges and mitigation measures

There are risks entailed in reducing the societal cost of agriculture and moving the system towards net positive impact. It is important to acknowledge the challenges and focus on targeted solutions.

	Challenges	Mitigation Measures
Economic	• The model only takes into account **GDP impact at farm level** (1.6% of GDP versus 7% of **GDP for wider food sector**). Reducing production levels will also hurt the broader sector – while the societal cost benefits driven by reduced production will be lower in the wider sector. • **Consumer prices,** even though not included in the model, will increase in the short-term due to declining yields and volumes, and costs for transitioning to low-impact, smart agriculture. • Price increase will be partially offset by a shift to more affordable plant-based proteins where also higher yield gains will be achieved. • The **farmer business case**, not fully included in the model, will face pressure: revenues would drop by -21% to -27% in alternatives 1 to 3, and even -58% in scenario 4. • While operating costs will decrease (through reduced use of feed, fertilizers, pesticides and energy) and price premiums are assumed for organic produce, the earning capacity for most farmers will deteriorate. Costs for transition are not included either.	• Stimulate investments into sustainable products, alternative proteins and agtech, leveraging the Dutch agriculture infrastructure and expertise • Adjust subsidy scheme to reflect the hidden costs of the current system towards incentivizing sustainable systems, thereby reducing consumer prices • Adjust subsidy scheme to reflect the hidden costs of the current system towards incentivizing sustainable systems, thereby incentivizing farmers to transition
Food security	• Scaling down production and focusing on plant-based proteins could **limit food variety** and fall short of **meeting all nutritional needs** for a balanced and healthy diet (EAT-Lancet, 2019). • This could increase **dependence on imports** of products that are harder-to-grow locally, such as nuts and legumes, potentially affecting supply stability and affordability. • Reduced exports will reduce the role of The Netherlands in contributing to **global food security** and might **shift environmental pressures** to other countries that increase their own output.	• Invest in protein innovation suited to Dutch conditions • Ensure diversified import channels and social safety nets for vulnerable groups • Strengthen European collaboration and regional trade • Stimulate other countries to join the transition and share knowledge on how this can be done based on lessons learned.
Model	• The modelling does not differentiate in the impact of the alternative systems on the **various food categories**: so the drastic reduction of plant categories in scenario 4 might not be required to reach planetary boundaries.	• Finetune the measures per food category to come to an optimized balance on economic and societal impact

Recommendations

Recommendations | Potential actions for key stakeholders

Recommendation to enable the transition

Government

Ministries have an opportunity to enhance their understanding of the public health and societal benefits of reducing agriculture's negative environmental impacts. Government's role in shifting the system to lower-impact production includes easing the financial burden of transition for farmers and promoting changes in consumer behaviour. Recommendations for action include:

- **Reform subsidy framework:**

Expand subsidies that prioritise environmental outcomes over scale of production and promote farming practices that boost environmental resilience. Phase out harmful incentives and reallocate funds to practices with lower societal costs.

- **Implement an emissions trading system:**

Introduce a cap-and-trade system for agricultural emissions. This would give farmers flexibility through trading rights and incentivise reductions in emissions.

- **Value and reward ecosystem services:**

Develop mechanisms to compensate and incentivise farmers for practices that support ecosystem services, such as improving soil health and water retention.

- **Adopt taxation strategies:**

Apply levies/ taxes on activities causing external costs to drive value chain change.

- **Launch public awareness campaigns:**

Foster a cultural shift towards sustainable agriculture by promoting its environmental, societal and health benefits.

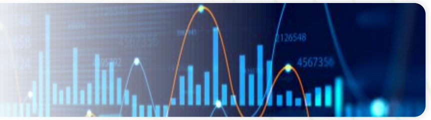
- **Promote organic food blending:**

Encourage mixing organic produce with conventional products to broaden consumer access beyond the current all-or-nothing options.

- **Support low-income households:**

Design policies to make sustainable and nutritious food affordable and accessible for low-income households, ensuring equity in the transition.

Banks



Banks have an opportunity to provide farmers with tailored access to capital and financial instruments to transition to lower-impact practices.

However, they face challenges in aligning economic objectives with environmental goals and redirecting funds effectively. Recommendations for action include:

- **Develop tailored financial products:**

Offer long-term loans and financial instruments designed to help farmers transition to more sustainable agricultural practices. These would provide farmers with access to the capital they need for upfront investments.

- **Establish sustainability incentives:**

Introduce financial products that reward environmentally-friendly farming, such as lower loan interest rates or financial packages.

- **Integrate sustainability criteria into credit and risk assessments:**

Factor environmental and social impacts into lending decisions and risk assessment models to encourage more sustainable business models in agriculture.

Insurers

Insurance companies have an opportunity to promote risk management strategies in agriculture that encourage sustainable farming.

while balancing risk and developing innovative solutions to address yield loss during the transition.

- **Incentivise healthy choices:**

Offer discounts or incentives to consumers who purchase organic or other sustainable food products. This would drive demand and support the sector's transition to more sustainable methods.

- **Coverage against yield loss:**

Offer financial protection to farmers during the transition, reducing risks from extreme weather and supporting a resilient agricultural system with broader benefits for society and the country.

Recommendations | Transition challenges and potential actions for actors in the agricultural value chain

	Farmers	Agribusiness/retailers	Input providers	Consumers
Challenges	• Farmers are at the forefront of the transformation towards lower-impact agricultural practices. They face significant challenges, including the need for **substantial upfront investment and transition capital.** • The **initial challenges of adopting alternative farming practices** can be daunting for farmers. • **Unpredictable revenues due to fluctuations in product prices** can also affect farmers' ability to transition.	• Agribusinesses including food processors, technology providers and retailers, would need to **adjust their supply chains** and **product portfolios** to align with a changing agricultural system. • Transitioning to alternative processes, new technologies and certifications may require significant **capital investment** and **operational changes**. • Ensuring **consistent quality and volume of food production** during the transition would bring logistical and financial risks.	• Providers of agricultural inputs, such as fertilisers and pesticides, would need to **maintain profitability** while **adapting their products** for lower-impact agricultural practices. • **Resistance to change** and the cost of developing alternative inputs could hinder innovation and the adoption of alternatives. • Shifting towards organic and lower-impact methods will require increased investment in systems to enhance the transparency and traceability of sourcing and production.	• Not all consumers are willing or able to **pay higher** prices for more sustainable products. • The proliferation of **sustainability labels in the food sector** can confuse consumers.
Recommendations	• Support lower-impact farming methods through funding and stability in demand and price, e.g. through long-term relationships with processors and retailers. • Create or join cooperatives and knowledge networks to share experiences and solutions. Develop a community culture that values learning in lower-impact production. • Collaborate with, and seek guidance from, value chain partners, such as innovation experts, to ease the adoption of new practices and technologies.	• Develop strategic partnerships with farmers, input providers and financial institutions to create integrated support ecosystems that facilitate the transition. • Drive innovation not only in product development and processing but also in retail formats, marketing, and consumer engagement to stimulate demand for lower-impact products. • Facilitate capacity-building initiatives for suppliers and farmers to ensure adoption of lower-impact practices	• Invest in research and development to create high-performance, lower-impact agricultural inputs such as biofertilisers, organic pesticides and soil enhancers. • Collaborate closely with farmers, agribusinesses and regulators to co-develop products tailored to the specific needs of lower-impact farming systems. • Encourage and support farmer training on the optimal use of lower-impact inputs to maximise efficacy and minimise waste.	• See p.45 for recommended government actions to address consumer challenges

Insight | Reforming subsidies to support transition to a lower-impact agricultural system

Transitioning to a lower-impact agricultural system with reduced societal costs would require strategic deployment of financial resources, including subsidies. And there is good reasons to do so. A recent report from the EAT-Lancet comission shows that that reshaping the food system costs $200-500 billion investment but could deliver a more than ten times return of $5 trillion a year through better health, restored ecosystems, and climate resilience. Three strategies that could accelerate the transition are:

- providing adequate financial support for the agricultural sector to make the transition;
- ensuring subsidies reward sustainable farming practices; and.
- distributing subsidies equitably between stakeholders, irrespective of scale.

Provide adequate financial support

Financial and fiscal incentives that promote positive environmental outcomes are currently limited in agriculture and the broader economy. Sectors such as energy and industry have disproportionate access to subsidies, while agriculture receives a comparatively minimal share. Notably, less than 4% of global climate finance is directed towards agriculture and food systems, even though these sectors contribute approximately one-third of global greenhouse gas emissions (World Economic Forum, 2023). Correcting this imbalance could catalyse transformative change within food systems and accelerate progress towards climate targets.

Ensure subsidies incentivise sustainable farming

Meaningful progress towards reducing environmentally harmful agricultural subsidies is insufficient. The Earth Track (2024) report estimates that USD 2.7 trillion of environmentally detrimental subsidies are given every year. Around 22% of these are allocated directly to agriculture, undermining global ambitions to curtail such subsidies.

Over €1 billion in Dutch agricultural subsidies may adversely impact biodiversity, according to an RVO report (2023) with large-scale agricultural operations, in particular, benefiting from substantial allocations. This may be a conservative estimate based on an incomplete view of subsidies (Visser et al., 2024).

Furthermore, some European fiscal policies continue to incentivise environmentally harmful practices. For example, a favourable 9% VAT rate on meat, particularly beef and veal, works against transition to agricultural systems with lower environmental footprints and societal costs (CE Delft, 2023).

Distribute subsidies equitably

Subsidy frameworks often favour the largest landowners and cooperatives. The bulk of payments under Pillar 1 of the European Common Agricultural Policy (CAP) are made to large beneficiaries. This raises concerns about equity and inclusivity within subsidy allocation.

Conclusion

Comprehensive reform of fiscal and financial instruments is an essential element of transitioning to an agricultural system that respects planetary boundaries. Such reform must aim to eliminate harmful incentives and introduce mechanisms that accurately reflect the true societal and environmental costs and benefits of agricultural practices.

Aligning subsidies and policy frameworks not only with productivity targets, but also with environmental and social goals, objectives, is an urgent priority. International dialogues and commitments confirm this, notably those within the Kunming-Montreal Global Biodiversity Framework.

Summary | Call to action

Our analysis highlights the substantial, yet hidden, societal costs of the current agricultural system in the Netherlands.

The authors of this report call for a serious debate on options to reduce the societal costs of agriculture by transitioning to lower-impact farming practices. Such a transition requires decisive and collective action by all stakeholders and value chain participants. Key actions are as follows:

Reform policies

Overhaul financial and fiscal incentives that promote unsustainable practices, tax activities that are causing external societal costs.

Introduce long-term rewards aligned with lower-impact practices.

Invest in innovation

Commit to funding smart technologies and nature-based solutions that improve yields while reducing environmental impacts.

Support farmers

Provide farmers with accessible capital, retraining programmes, and effective risk mitigation tools to transition confidently to lower-impact farming methods.

Engage consumers

Launch awareness campaigns that promote the health and environmental benefits of lower-impact diets.

Ensure everyone has equitable access to nutritious food.

Collaborate internationally

Collaborate with trade partners to harmonise standards and policies.

Prevent leakage of environmental impacts and societal costs beyond our borders.

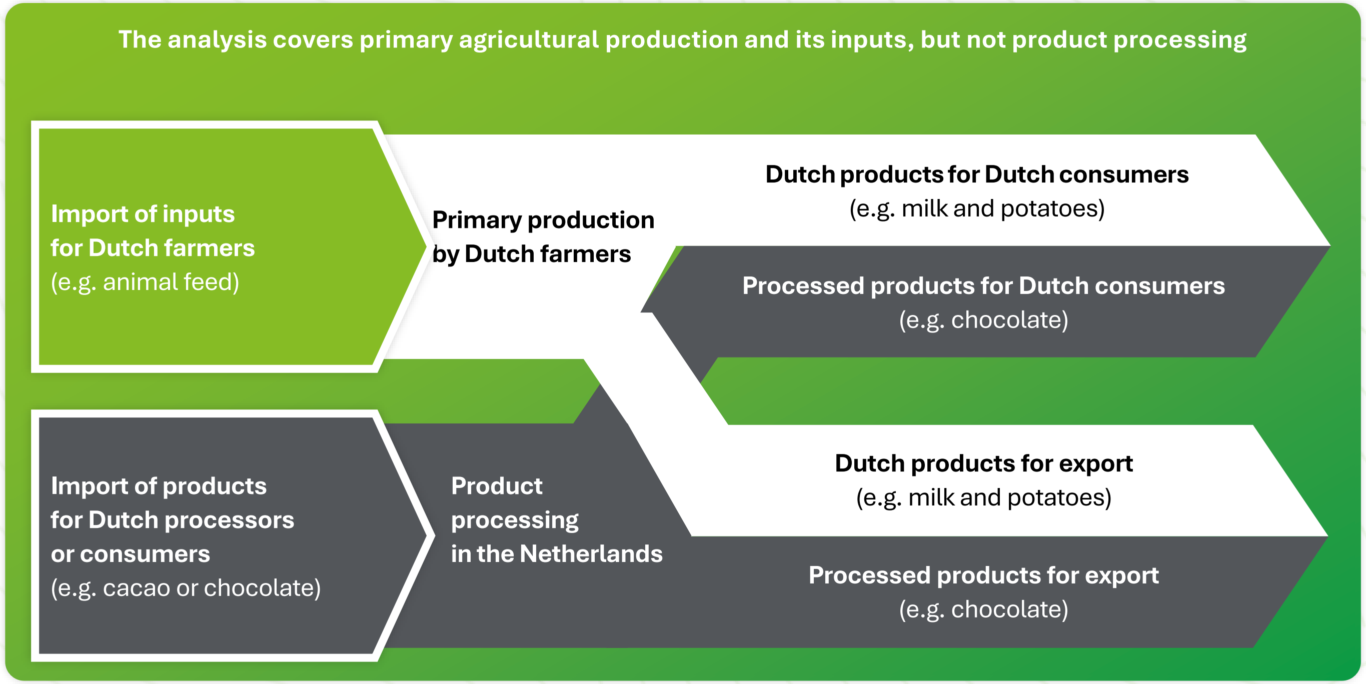
Methodology

Methodology | The analysis covers primary food production in the Netherlands

We assess the economic benefits and societal costs of food production in the Netherlands, related to import, production and consumption.

This analysis focuses on the impacts of food produced in the Netherlands, covering key sectors including arable farming, horticulture, fruit cultivation, and dairy, meat and egg production. It includes imported materials that are essential to primary production, such as animal feed, fertilisers and pesticides.

It excludes the processing of primary production into secondary products and other downstream activities, such as transport and retail[1]. It also excludes products imported solely for consumption in the Netherlands (e.g. bananas or Irish beef); products that are processed, but not produced in the Netherlands (e.g. cacao); and products that are imported by other countries via the Netherlands. The environmental impacts of animal feed production in the Netherlands is not included because these impacts are already accounted for in the life cycle assessment (LCA) data of animal products.



In scope: environmental impacts and societal costs *outside* the Netherlands

In scope: environmental impacts and societal costs *in* the Netherlands

Not in scope

[1] The LCA data used for GHG emissions, nitrogen, phosphorus, land use and water consumption, extend to the point of distribution (as defined by the smallest RIVM LCA system boundary), which means some processing activities are included. These processing impacts are assumed to be minor compared with the overall farm-level impacts. However, it is important to note that impacts from primary production exclusively would be slightly smaller than the results of this analysis. For all other impact categories, the scope of analysis is limited strictly to primary production.

Methodology | Products included in the analysis

We calculated the economic benefits and societal costs of producing 11 different types of agricultural products

Product groups are based on Statline from CBS and include all products for human consumption produced in Dutch agriculture.

Beef

All beef cattle raised for meat, including steers and heifers; excludes dairy cows not used for beef.

Pork

All pigs reared for meat production, including sows, boars and piglets destined for pork products.

Poultry

All chickens, turkeys, ducks and other fowl raised for meat; excludes laying hens.

Eggs

Eggs produced by laying hens on Dutch farms, primarily chicken eggs.

Milk

Raw cow's milk produced on Dutch dairy farms.

Other animal products

Animal-based products not classified on the left, e.g. goat and sheep meat and milk, rabbits and minor livestock categories.

Vegetables

All field- and greenhouse-grown vegetables, such as tomatoes, carrots, cucumbers and leafy greens.

Fruit

All orchard- and greenhouse-grown fruit, including apples, pears, berries, and other soft/hard fruit.

Potatoes

All types of potatoes, including table potatoes and those for processing.

Grains

All cereal crops such as wheat, barley, rye and oats produced for human consumption.

Other plant products

Plant-based products such as sugar beet, oil seeds and other miscellaneous crops.

Methodology | Calculating economic benefits

To calculate the economic impact of alternative agricultural systems, we analysed revenues, costs and value added to GDP.

Economic impact calculation

The analysis determines the economic impact of adopting alternative agricultural systems by examining how the value added to GDP by primary production would change.

The calculations include predicted changes in farmers' revenues and costs for each cumulative alternative, and the resultant change in overall value added.

The costs of transitioning between alternative systems are not included.

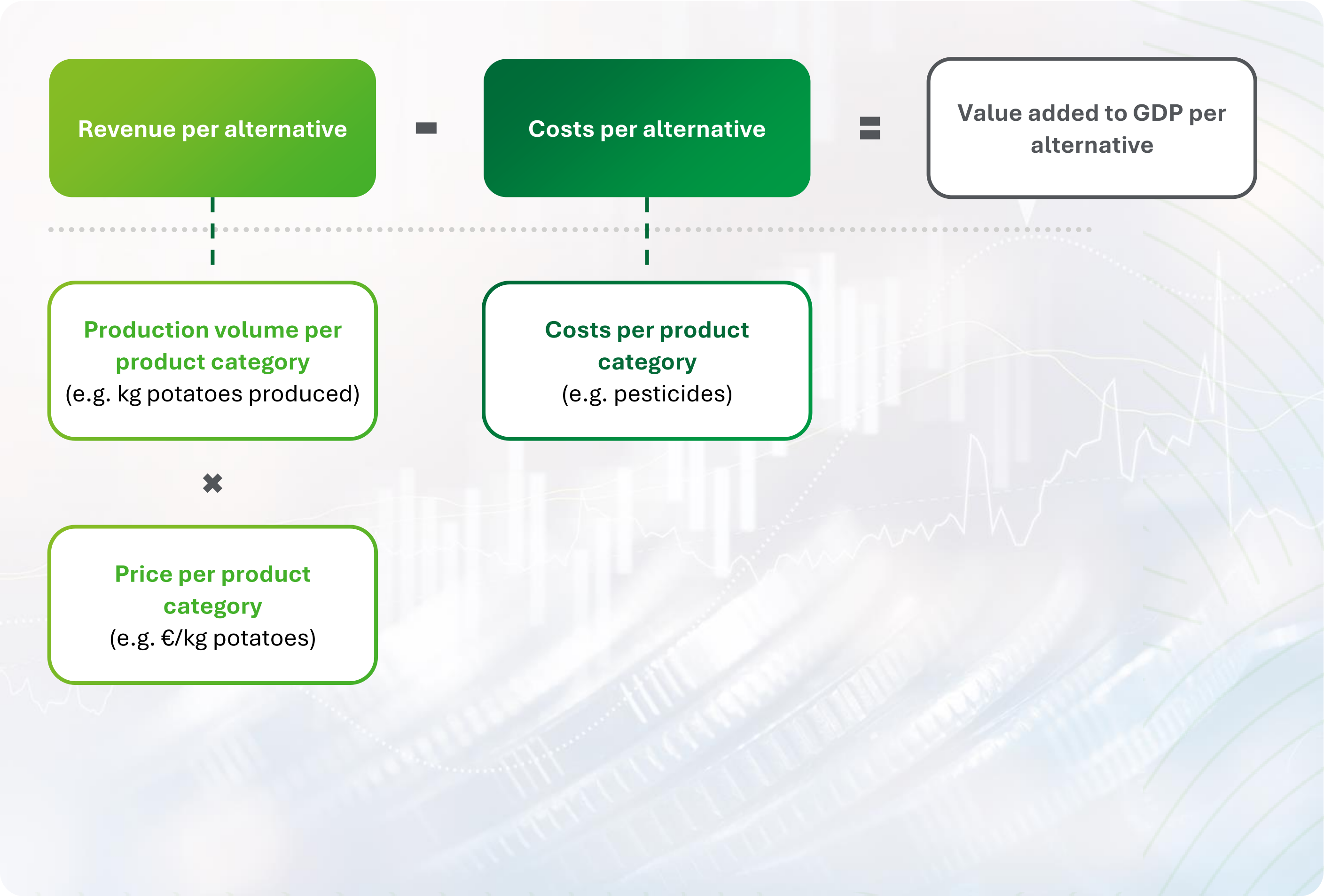
Revenue calculation

Calculations of the revenue impacts of alternative systems are based on assumed product volumes and prices. For example, our analysis of a 100% organic system assumes the lower yields and higher product prices typical of organic farming practices.

Cost calculation

Similarly, the analysis calculates expected changes in farmers' costs between the various alternative systems modelled. It includes expenses such as pesticides, fertilisers, concentrate feed and energy.

In the example of 100% organic farming, costs for pesticides and fertilisers are significantly reduced.



Methodology | Assumptions applied for calculation of revenues and costs

We calculated economic impacts across all alternatives by analysing revenue and cost changes for each product category, driven by price, production volume and cost category variations.

Revenue assumptions

- Farmers' revenues may change under different agricultural systems, for example due to changes in product prices or in production volumes.
- Price increases have been estimated based on the price difference between conventional and organic products.
- Production volume changes are based on predicted changes in yields resulting from different farming practices. For example, a transition to organic farming would result in lower yields for certain products.

Cost assumptions

- The analysis calculates costs based on the following selection of farm inputs: fertilisers, energy, pesticides and animal feed. The model assumes changes in the use of these inputs under the various alternative agricultural systems (although we acknowledge this may not always be the case in practice).
- Pesticide use is not eliminated completely in any of the alternatives. Organic farming may still use pesticides during severe pest outbreaks.
- The introduction of smart innovation reduces consumption of diesel and gas, for example by replacing them with (green) electricity which reduces costs.
- In the alternatives, the use and cost of chemical fertilisers is significantly reduced.
- Organic animal feed has a higher cost than concentrated feed.

	2023 production volume (m kg)	Predicted change in production volume under each alternative system [1] (%)				Price differential: organic vs conventional[4] (%)
	Current system[3]	1	2	3	4	
Beef	434	-36%	-36%	-48%	-75%	+30%
Pork	1,456	-65%	-65%	-72%	-87%	
Poultry	851	-80%	-80%	-83%	-92%	
Raw milk	13,527	-40%	-40%	-51%	-77%	+23%
Eggs	609	-71%	-71%	-77%	-89%	+30%
Other animal[2]	21	-58%	-58%	-66%	-84%	
Vegetables	4,860	-15%	+4%	+43%	-32%	
Fruits	619	-15%	-15%	+17%	-44%	
Potatoes	6,434	-36%	-36%	-12%	-58%	
Grains	1,340	-21%	-4%	+33%	-37%	
Other plant-based[2]	7,086	-15%	+4%	+43%	-32%	

[1] Changes to volumes are shown as the reduction or increase compared to the current agricultural system.
[2] Average of all animal-based or plant-based product prices.
[3] Based on CBS Statline, 2023 corrected for current volume of organic production.
[4] Nieuweoogst. Prijzen biologisch, Consumentenbond. Organic products in supermarkets cost an average of 48% more than conventional products, but not all this price-premium is passed on to the farmer. We also assume that the current price differential would decrease if organic farming were widely adopted across the Netherlands. In the analysis, we have assumed a 30% higher price for organic products in all categories, except for milk where the market is more mature and more accurate data is available.

Methodology | Calculating societal costs

We quantified societal costs related to the following environmental impacts of agriculture. These costs were monetised using pricing data from CE Delft, True Price and other sources.

Environmental theme	Environmental impact	Price (in €$_{2023}$)[1]		Impact on society	Monetisation source
Climate change	GHG emissions (CO_2-eq)	0.14	€/kg CO_2-eq	Negative effects on the economy, health of humans and ecosystems	CE Delft 2023
Air pollution	Particulate matter (PM_{10} , $PM_{2.5}$)	130.48 74.73	€/kg $PM_{2,5}$ €/kg PM_{10}	Negative human health impacts, such as lung diseases	CE Delft 2023
Water use	Fresh water consumption	0.15	€/m^3	Affects the availability of water and can lead to scarcity, affecting human health, biodiversity and stocks of aquatic life	CE Delft 2023
Water pollution, Marine eutrophication	Nitrogen (N)	15.37	€/kg N-eq	Negative impacts on ecosystems	CE Delft 2023
Air pollution	Ammonia (NH_3)	53.16	€/kg NH_3	Negative effects on human health and ecosystems	CE Delft 2023
Water pollution, freshwater eutrophication	Phosphorus (P)	5.96	€/kg P-eq	Negative impacts on ecosystems	CE Delft 2023
Land use (adjusted for biodiversity loss)	High intensity pasture use	1276	€/ha*year	Displaced ecosystems lead to biodiversity loss and the loss of ecosystem services, which in turn affects human well-being. In land use impact calculations, the biodiversity loss refers specifically to losses caused directly by using land for agriculture. It does not include biodiversity losses from other environmental impacts such as ammonia, GHG emissions, or soil or air pollution. These are assessed separately.	True Price, 2021
	High intensity cropland use	1640	€/ha*year		
	Light intensity pasture use	729	€/ha*year		
	Minimal intensity cropland use	911	€/ha*year		
Pesticides	Pesticide use	440	mln € / yr (for NL)	Negative effects on human health. The analysis used the average of pricing from five different studies as a proxy for the societal cost of pesticide use. This price was applied to the Netherlands based on population size.	Pimental 2005 Rufo 2024 Fantke 2012 Alliot 2022 Bourguet 2016
Soil quality	Increased water storage, higher carbon, nitrogen and biodiversity in the ground	480	mln €/year	Soil quality interacts with other environmental impacts including carbon, water, biodiversity and nitrogen. Assumptions made for the alternatives in this analysis include: a best case of1t CO_2/ha additional carbon absorption; an additional 187 m^3 of water retained per hectare per percentage point increase of organic matter in the soil (a 5% increase per year of organic matter was estimated).	Gomiero 2011 Leifeld 2010 FIBL 2024 Stowa 2019

[1]Original prices in the data sources were corrected for inflation to represent prices in 2023 using a five-year rolling average inflation factor.

Methodology | Calculating the societal cost of climate change, water consumption, water pollution and land use

We used agricultural production volumes and life cycle assessment data to quantify these societal costs.

To calculate the environmental impacts of Dutch food production, and the related societal costs, in terms of **climate change, water consumption**, **water pollution** (nitrogen and phosphorus) and **land use**[1] we used a life cycle assessment (LCA)-based approach. This approach enables comprehensive analysis of impacts throughout the life cycle of agricultural products, from the extraction of raw materials through production and processing, up to distribution. The analysis therefore includes not only the environmental impacts of Dutch farms, but also impacts in the upstream value chain. Upstream impacts result from the production of materials used to produce crops and animal products in the Netherlands, such as fertilisers and animal feed. The analysis also includes the processing of farm products into retail-ready products, e.g. the processing of cows into beef products. The approach does not account for differences in impact specific to locations, such as proximity to cities or natural areas.

For both conventional and organic products, environmental impacts and associated societal costs were calculated by combining LCA data from RIVM, correcting it with LCA data from Agribalyse and monetising the impact with shadow prices from CE Delft and True Price.

Conventional production:	**Production volume** (e.g. kg potatoes)	×	**Impact factor RIVM** (e.g. kg CO_2-eq/kg potatoes)	×	**Shadow price for societal cost** [3] (e.g. € /kg CO_2-eq)	=	**Societal costs of agricultural production** (€)
Organic production:	**Production volume** (e.g. kg potatoes)	×	**Impact factor RIVM** (e.g. kg CO_2-eq/kg potatoes) **Corrected with Agribalyse** (% difference organic/conventional)	×	**Shadow price for societal cost** [3] (e.g. € /kg CO_2-eq)	=	**Societal costs of agricultural production** (€)

[1] Due to limited LCA data availability, not all environmental impacts and associated societal costs could be calculated taking an LCA approach. This is the case for air pollution by nitrogen (ammonia), air pollution by particulate matter (PM_{10} and $PM_{2.5}$), pesticides and soil health. Our methodology to calculate these impacts is explained separately in this methodology.

[3] Societal costs included in the shadow prices may encompass healthcare expenses, economic losses, such as crop damage and infrastructure repair, and decreased productivity from adverse health effects on the workforce. See the overview of shadow prices.

Methodology | Calculating the societal cost of air pollution

Additional environmental impacts were calculated based on country level data to get a more holistic picture of the societal costs.

Air pollution – often in the form of ammonia (NH_3) or particulate matter (PM_{10} and $PM_{2.5}$) – results mainly from livestock and the use of fertilisers and energy. It is a significant contributor to the environmental impacts and societal costs of farming.

Negative effects of agricultural air pollution

- Environmental degradation: Ammonia emissions contribute to the acidification and eutrophication of soils and water bodies, harming biodiversity and reducing the resilience of ecosystems.
- Health impacts:
  - Ammonia emissions can lead to respiratory diseases and asthma (RIVM, 2025).
  - Particulate matter can penetrate deep into the lungs and bloodstream, increasing the risk of respiratory illnesses, asthma, cardiovascular problems and premature mortality (RIVM, 2025).
- Societal costs: The combined environmental and health impacts of these air pollutants lead to substantial costs for society, including increased healthcare expenses, reduced labour productivity and environmental remediation.

Our approach to quantifying the societal costs of air pollution

Comprehensive data on ammonia and particulate pollution is not available in LCA databases. We therefore quantified emissions and applied established shadow prices to estimate the monetary cost to society. We used a "top-down" approach, meaning that the analysis excludes air pollution impacts in the value chain.

Ammonia emissions to air

We determined total agricultural ammonia emissions in the Netherlands using national data for 2022 from CLO (Compendium voor de Leefomgeving, 2024). This dataset provides a robust picture of sector-wide ammonia emissions to the air.

For each alternative agricultural system in our impact analysis, we recalculated ammonia emissions based on adjusted livestock numbers. The recalculated ammonia emissions (in kg per year) were multiplied by the shadow price for ammonia as established by CE Delft 2023.

Particulate matter emissions to air

We sourced emissions data for PM_{10} and $PM_{2.5}$ from Emissieregistratie (Rijksoverheid, 2022), which provides detailed, source-specific information on the emission of particulate matter from agricultural activities.

- In our analysis of the current agricultural system, we calculated societal costs by multiplying reported emissions of PM_{10} and $PM_{2.5}$ by their respective impact prices (CE Delft 2023). These impact prices capture the health and economic costs caused by fine particulate air pollution in society.
- In Alternative 1 (Low-impact Farming), we assumed that particulate emissions from synthetic fertilisers fall to zero, given that organic farming does not use synthetic fertilisers. Additionally, emissions from animal production decrease due to a significant reduction in livestock numbers, since organic regulations require greater space per animal.
- In Alternative 2 (Smart Innovation), we modelled a reduction in particulate matter emissions from energy use due to increased adoption of smart technologies, electrification and a shift to green energy sources across the sector.
- In Alternative 3 (Protein Shift), we assumed an increase in particulate emissions from plant-based production due to intensified crop cultivation and processing—reflecting the transition towards producing more plant-based protein. However, this increase is partially offset by a decrease in emissions from animal production.
- In Alternative 4, particulate matter emissions are reduced in line with the 47% reduction in production levels from Alternative 3.

Methodology | Calculating the societal cost of pesticide use

We used data from five separate studies to set a societal cost for the impact of pesticide use.

Pesticides play a significant role in modern agriculture, however, their use is a double-edged sword with both positive and negative impacts.

Positive impacts of pesticides

- Increased crop yield: Pesticides help prevent crop losses caused by pests, diseases and weeds, leading to higher productivity and food security.
- Cost-effectiveness: By protecting crops from damage, pesticides can reduce the need for more costly agricultural practices or interventions.
- Quality improvement: Pesticides can improve the aesthetic appeal and quality of produce, ensuring that fruits and vegetables are marketable and meet consumer expectations.

Negative impacts of pesticides

- Environmental impact: Pesticides can contaminate soil, water sources and organisms other than the pests targeted, leading to biodiversity loss and ecosystem imbalances.
- Health risks: Growing research highlights the potential health risks associated with pesticide residues on food. Long-term exposure to these residues has been linked to various health issues, including:
  - *Endocrine disruption:* Certain pesticides can interfere with hormone systems, potentially leading to reproductive issues and developmental problems.
  - *Neurological effects:* Some studies suggest a correlation between pesticide exposure and neurological disorders, including Parkinson's disease.
  - *Cancer risks:* Growing evidence indicates that prolonged exposure to specific pesticides may increase the risk of certain cancers, such as non-Hodgkin lymphoma.

Emerging research on pesticide residues

A recent study by the Ramazzini Institute showed that long-term exposure to glyphosate and its herbicides in rats, resulted in a higher chance of developing different types of cancer, including leukemia, indicating that these chemicals can cause cancer. This raises concerns about the long-term consumption of conventionally farmed produce. The presence of pesticide residues has become a critical factor in food safety discussions, prompting calls for stricter regulations and greater consumer awareness.

How we quantified the societal costs of pesticides

Many studies have been conducted on the negative health impacts of pesticide use, primarily focusing on the farmers and workers who are directly in contact with them.

However, a meta-study from Bourguet 2016 suggests that recent studies have under-estimated total health costs related to fatal chronic exposure to pesticides by as much as ten times.

In our analysis, we have set a societal cost for pesticide use based on the average of pricing in five separate studies: Rufo 2024, Fantke 2012, Alliot 2022, Pimental 2005, Bourguet 2016. We have adjusted the pricing to the Dutch context based on population. The pricing has also been corrected for inflation. This resulted in a current societal cost of pesticide use in the Netherlands of approximately € 440 m/yr.

Methodology | Calculating the societal benefits of increased soil health

The analysis focuses on the benefits of increased carbon sequestration and water retention in healthy soil.

This analysis considers two metrics of soil health: soil organic carbon (SOC) and water availability. Assumptions have been made on the amount of carbon healthy soil can hold, and the amount of water Dutch soil needs for agriculture.

Positive impacts of soil health included in the analysis

- Increased water storage: Healthy soil has a more porous structure and more organic matter than less health soils. It is therefore better at absorbing and retaining water.
- Higher carbon, nitrogen and biodiversity: High levels of carbon, nitrogen and biodiversity in the soil boost nutrient availability, soil life and the resilience of plants.

Impacts not included

- Improved yield and crop quality: This impact is included in Alternative 2 (Smart Innovation) in which intercropping boosts yields and soil health. It is therefore excluded from the wider analysis to avoid double counting.
- Higher disease resistance: The contribution of soil health to disease resistance is highly dependent on context. It is also difficult to isolate its effects from those of other practices to promote disease resistance. We therefore excluded this impact from the analysis to avoid overestimating benefits.

Emerging research shows benefits of soil health and organic farming

Recent research has shown that organic farming improves soil quality by increasing SOC and water retention.

Studies have shown that organic practices can sequester up to 1 ton of CO_2 per hectare per year, highlighting the potential of organic farming for carbon absorption and climate mitigation.

Additionally, for every 1% increase in soil organic matter (SOM), organic farming can retain an extra 187 cubic meters of water per hectare, enhancing soil moisture availability. These findings emphasize the environmental benefits of organic farming and its potential to promote healthier, more resilient soils.[1]

How we quantified the societal benefits of soil health

- SOC: We estimated the relationship between SOC and CO2 absorption using a conversion factor of 1t C/ha, which equates to 3.67 t of CO2/ha. This factor was applied to all non-organic farmland in the Netherlands.
- Water storage: We have assumed a 5% increase of SOM per year in organic farming.

These impacts are quantified as shown below.

Indicators of increased soil quality	Increase of indicator in organic farming	Amount in conventional farming practices	Amount in organic farming practices	Difference
Soil organic carbon (SOC)	~1t CO_2/ha per year (best case)	-90 kg SOC/ha per year	110 kg SOC/ha per year	200 kg SOC/ha per year
Water availability / Water holding	187 m³/ha per year	N/A	N/A	Every 1% increase in soil OM will help soils hold up to 20,000 gallons more water per acre

[1] In this analysis, we assume that the benefits of organic farming in terms of CO_2 sequestration and water retention can be considered compensatory factors. However, these benefits are not explicitly integrated into the planetary boundaries framework applied in this study.

Methodology | Calculating nutritional value

The analysis uses protein and energy production as key measures of the nutritional value provided by alternative agricultural systems.

The analysis determines how much animal and plant-based protein and energy (kcal) each alternative agricultural system would produce for each product group. Total energy and protein was calculated using product-specific values from the NEVO database.

We then compared total protein production of each alternative with the minimum dietary requirement of the Dutch population, based on 18 million people with an average daily intake of 59 grams of protein and 2,300 kcal per person. We divided the total kcal production per alternative by this minimum requirement to determine the capacity of each alternative to meet national dietary needs.

We acknowledge that the Netherlands currently produces significantly more food than is required by its own population. A substantial proportion of current production is intended for export. However, for the purpose of this analysis, we focus on exploring domestic nutritional rather than export potential.

Protein and energy levels of product groups in this analysis

Product group	Source	Protein/kg	Energy Kcal/kg
Beef	Ground beef - RIVM	0.189	2,250
Pork	Minced pork - RIVM	0.183	1,770
Poultry	Raw chicken with skin - RIVM	0.034	2,180
Raw milk	Raw milk - RIVM	0.123	710
Eggs	Raw chicken egg - RIVM	0.146	1,320
Other animal-based	Average of animal products	0.146	1,646
Fresh vegetables	Raw onion - RIVM	0.013	370
Fresh fruits	Apple with skin - RIVM	0.003	560
Potatoes	Raw potato - RIVM	0.020	880
Grains	Wholewheat flour - RIVM	0.144	3,300
Other plant-based	Average of plant products	0.045	1,278

Alternative1 | Calculating yield reduction in organic farming

Calculations of livestock yield reductions in organic farming are based on the increase required in space per animal

Organic farming yields are, on average, 18.4% lower than conventional farming. In warm temperate climates, yields are more than 21% lower (De la Cruz et al. (2023)) Crop type, region and soil type and health can also affect this difference.

How we quantified the impact of organic agriculture on yields

We conducted research to determine how transitioning to organic production would likely affect yields compared with conventional farming. The expected percentage change in yield was applied to the total conventional yield for each product group, giving an adjusted yield figure for organic production.

For plant production, we used Research Institute of Organic Agriculture FiBL as the primary source for long-term yield reduction estimates. Its findings have been corroborated by Dutch studies (e.g. WUR, 2023).

For livestock farming, organic regulations require more space per animal, which reduces yields because fewer animals can be raised. We calculated constraints based on land availability per farmer. The yield reductions used in our calculations are shown in the table on the right.

Considerations and limitations

Not all Dutch soil types may be equally suited to organic crop farming. However, a detailed analysis of yield reductions per soil type is outside the scope of this research.

Expected yield reductions per product group in organic farming

Product group	Expected yield reduction[2]	Current space per animal	Space per animal in organic production	Difference
Beef	-36%	5.4 m² per cow	8.5 m² per cow	X 1.6
Pork	-65%	0.8 m² living space and 0 m² outdoor space per pig	1.3 m² living space and 1 m² outdoor space per pig	X 2.9
Poultry	-80%	0.43 m² per broiler[1]	2.1 m² per broiler	X 4.9
Eggs	-71%	1.19 m² per laying hen[1]	4.16 m² per laying hen	X 3.5
Milk	-40%	Conventional average yield compared to intensive organic farm yield		
Other *(average of the above)*	-51%			
Fresh vegetables	-15%			
Fresh fruit	-15%			
Potatoes	-36%			
Grains	-21%			
Other plant product	-15%			

Note on limitations of yield reduction calculation

Calculations of yield reductions and space requirements for organic livestock agriculture carry significant uncertainty due to reliance on assumptions we have used. Our calculations are based on current animal housing systems and assume a constant land area used for livestock production. This may not reflect future realities if the sector fully transitions to organic methods. According to WUR, 2023, in organic production, emissions per animal may increase due to slower growth and more space required per animal. This could offset emissions reduction from a lower overall number of animals. Additionally, the model does not consider innovations in animal housing design or emission mitigation technologies. Basing calculations solely on space per animal may overestimate production. Including stricter constraints, such as conversion to organic animal feeds or limits on imported feed, would likely lower output further.

[1] Weighted average based on current distribution of husbandry systems in the Netherlands and their corresponding space requirements per animal

[2] It is assumed that the amount of agricultural land (Ha) will remain the same in a 100% organic production alternative

Alternative 2 | Calculating the effect of smart innovation on organic farming

The analysis assumes benefits from introducing five smart innovations to a 100% organic farming system

Alternative 2: smart innovations and their assumed effects

Assumed benefits for calculations	-37% CO_2	-13% water	-2% PM	-14% costs	+22% yield

Innovation	Assumed effects	Source
Electrification of agricultural vehicles and sustainable energy sourcing: Transition from traditional fossil fuel-powered farm machinery to electric agricultural vehicles and equipment. Use solar and/or wind energy and biogas in agricultural operations.	• CO_2 emissions of machinery and electricity **reduced by 74%** • Particulate matter of machinery **reduced by 74%** • Annual energy costs **reduced by 25%**	Lagnelöv 2023 Eldeeb 2023
Water management technology: Implement smart irrigation, such as drip irrigation and water recovery systems.	• Increased irrigation efficiency • Water consumption **reduced by 38%**	Canaj 2022
Precision agriculture: Monitor plants and animals closely to provide precise treatment as needed. Technologies include GPS, sensor technology, ICT and robotics.	• CO_2 emissions **reduced by 13%**	Canaj 2022
Circular agriculture: Use by-products from one activity as inputs for another, e.g. the use of compost or manure; use of residual nutrients and organic matter from other crops; enhancing soil fertility and reducing waste.	• Reduced waste • More efficient use of inputs, leading to higher yields • GHG emissions **reduced by 70%** (mainly in plant-based production)	Hoogstra 2024
Intercropping and pixel farming: Cultivate multiple crops simultaneously on the same field to optimise the use of resources and ecological processes, compared with monocultures.	• Yields **increased by up to 22%** for certain crops.	Li,2021

Alternative 3 | Calculating land use transformation for the protein shift

In today's Dutch agricultural system, approximately 40% of protein produced for human consumption is plant-based.

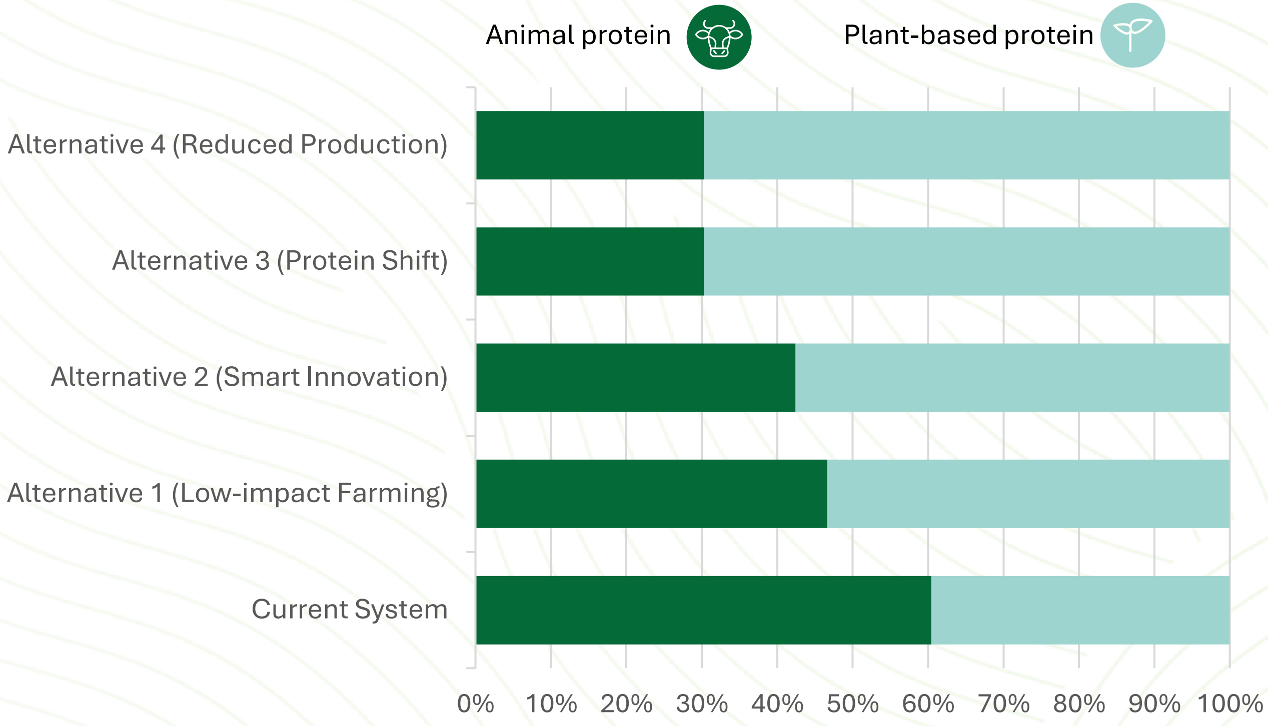
In Alternative 3, the total agricultural area remains the same as in the current system, but 18.5% of livestock land is reallocated to crop production to achieve a 70% plant-based and 30% animal-based protein output.

No new crop types are introduced; existing Dutch crops are expanded in proportion to current production.

Production volumes, yields, and input costs are adjusted to reflect the increased plant-based output and reduced livestock numbers.

Environmental and economic impacts are recalculated using life cycle assessment (LCA) data and shadow prices for each product group.

Ratio animal vs. plant-based protein production



Alternative 4 | Assessing agricultural systems against planetary boundaries

Planetary boundaries represent quantifiable limits to human activity in order to maintain the stability of the Earth's systems, the long-term health of ecosystems and safety of humanity.

The planetary boundaries specific to agriculture used in this analysis are taken from a report by the EAT-Lancet commission. The Commission identified six key Earth system processes impacted significantly by food production: climate change, nitrogen and phosphorus cycling, water use, land-system change, and biodiversity loss. The Commission has set scientific targets for each of these processes to define a safe operating space for food production systems. The boundaries, if exceeded, could lead to irreversible and potentially catastrophic changes to the Earth's systems.

We included five of these planetary boundaries in this analysis. We assessed the current agricultural system and the cumulative alternative systems to assess the extent to which they operate within, or exceed, these five boundaries.

It was not possible to measure the performance of the alternatives against the biodiversity planetary boundary due to a lack of relevant LCA and Netherlands-specific data.

In Alternative 4 (Reduced production) we set out specifically to explore what it might take to bring the Netherlands agricultural system within the boundaries.

We allocated each boundary based on the population of the Netherlands in 2025 compared with the global population1. The table below provides the calculation of these boundaries.

Environmental impact	Unit	Global planetary boundary	Global population in 2025	Boundary per person in 2025	Dutch population in 2025	Boundary for the Netherlands
Climate change	tonnes CO_2-eq/yr	5,000,000,000	8,200,000,000	0.610	18,000,000	10,975,610
Nitrogen cycling	kg N/yr	90,000,000,000	8,200,000,000	10.976	18,000,000	197,560,976
Phosphorous cycling	kg P/yr	8,000,000,000	8,200,000,000	0.976	18,000,000	17,560,976
Freshwater consumption	km^3 blue water/year	2,500	8,200,000,000	0.000000305	18,000,000	5.49
Land-system change	km^2 cropland use	13,000,000	8,200,000,000	0.002	18,000,000	28,537

[1]Attributing planetary boundaries to individual countries based solely on population size does not account for differences in resource availability, consumption patterns, or historical responsibilities. However, due to the lack of globally agreed allocation methods and for reasons of practicality and comparability, we have chosen a population-based approach in this analysis.

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