Opportunities and threats for the Dutch agricultural sector arising from shifting climate zones in Europe

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Climate change is putting significant pressure on the resilience and flexibility of agricultural systems in the Netherlands. Soil degradation, salinisation, heat and drought stress on sandy soils, increased pest and disease pressure due to milder winters and changing precipitation patterns all pose increasing crop risks. This report outlines a number of adaptation pathways through which the Netherlands can remain competitive in the face of shifts in production areas due to climate change. They include strategies such as strengthening climate-resilient food supply, including investments in trade and logistics, optimising production within multifunctional landscapes with limited space, promoting controlled agriculture for resilience and switching to high-value crops such as legumes. Together, these strategies highlight how Dutch agriculture can leverage its existing strengths while adapting to the changing climate and policy context.

Klimaatverandering zet de veerkracht en flexibiliteit van de landbouwsystemen in Nederland aanzienlijk onder druk. Bodemdegradatie, verzilting, hitte- en droogtestress op zandgronden, verhoogde plagen- en ziektedruk door mildere winters en veranderende neerslagpatronen brengen allemaal toenemende teeltrisico's met zich mee. Dit rapport schetst een aantal adaptatiestrategieën waarmee Nederland concurrerend kan blijven in het licht van verschuivingen in productiegebieden als gevolg van klimaatverandering. Ze omvatten strategieën zoals het versterken van klimaatbestendige voedselvoorziening inclusief investeringen in handel en logistiek, het optimaliseren van de productie binnen multifunctionele landschappen met beperkte ruimte, het bevorderen van gecontroleerde landbouw voor veerkracht en het overschakelen op hoogwaardige gewassen zoals peulvruchten. Samen benadrukken deze strategieën hoe de Nederlandse landbouw haar bestaande sterke punten kan benutten en zich tegelijkertijd kan aanpassen aan de veranderende klimaat- en beleidscontext.

Key words: Climate change, Dutch agriculture, competitiveness, adaptation strategies

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Preface

Climate change is increasingly reshaping global agricultural systems, with profound implications for food production and land use. In Europe, these transformations are already disrupting traditional agricultural zones, necessitating adaptation and long-term strategic planning.

This report, *Opportunities and threats for the Dutch agricultural sector arising from shifting climate zones in Europe*, offers a vital contribution to understanding these critical dynamics. Commissioned by the Ministry of Agriculture, Fisheries, Food Security and Nature, it directly addresses a key parliamentary motion from 2022, highlighting the potential for Dutch agriculture to strengthen its role in European food production amidst these changes.

The report examines the biophysical consequences of climate change in conjunction with socio-economic drivers, as well as growing challenges related to extreme weather events, pests, and diseases. Building on this analysis, four adaptation strategies are proposed to illustrate how the Dutch agricultural sector can respond effectively to these challenges—capitalising on its strengths to enhance resilience and maintain a leading role in European food production.

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Wageningen University & Research

Summary

This report, commissioned by the Ministry of Agriculture, Fisheries, Food Security and Nature, examines the medium-term (2050) implications of shifting climate zones in Europe for the competitiveness of the Dutch agricultural sector. It addresses a parliamentary motion from 2022, which posited that climate change might enhance the Netherlands' role in European food production.

The analysis integrates biophysical impacts of climate change with socio-economic drivers and evolving pressures from extreme weather, pests, and diseases. While acknowledging that climate change impacts in the Netherlands are projected to be less severe than in Southern Europe, the report highlights significant domestic pressures on agricultural resilience. These include soil degradation, salinisation, heat and drought stress on sandy soils, increased pest and disease incidence due to milder winters, and altered precipitation patterns, all contributing to heightened crop risks. The study reveals that despite potential benefits from extended growing seasons for certain crops, these gains are unlikely to offset broader losses. A critical knowledge gap is identified in recent, context-specific research on the biophysical impacts of climate change on Dutch agriculture, noting a continued reliance on foundational studies from the early 2000s. This underscores the urgent need for renewed investment in applied climate-agriculture research to inform robust national and regional adaptation strategies.

Through a detailed SWOT analysis, the report identifies the sector's key strengths, such as technological leadership in precision farming and greenhouse horticulture, advanced infrastructure, and strong EU market integration. Concurrently, it exposes weaknesses including susceptibility to extreme weather, heavy reliance on global trade, and 'lock-in' effects from established practices. Opportunities arise from new crop suitability, growing demand for sustainable food, and emerging carbon credit markets, while threats encompass water scarcity, new regulatory burdens, and market volatility.

To navigate these complexities, the report proposes four strategic adaptation pathways for Dutch agriculture:

1. *Strengthening Climate-Resilient Food Supply*: Leveraging the Netherlands' international business and distribution networks to act as a stabilising force in the EU food market during climate-induced shortages.
2. *Farming within Limits*: Maintaining high-value, reliable agricultural output through spatial efficiency and sustainable practices within increasingly multifunctional landscapes, adapting to reduced land availability and stringent environmental limits.
3. *Scaling Controlled-Environment Agriculture*: Further investing in and developing advanced greenhouse farming systems to mitigate climate-related challenges, capitalising on existing Dutch expertise.
4. *Scaling High-Value Crop Production via Leguminous Plant Proteins*: Advocating for a strategic shift towards cultivating legumes, driven by consumer demand for plant-based proteins, their climate resilience, and benefits for soil health.

Collectively, these strategies emphasise a proactive shift towards resilience, circularity, and value-added production, aiming to maintain and enhance the Netherlands' competitive position and contribution to European food security in a changing global climate. The report concludes with a call for renewed investment in modern climate-agriculture research to ensure future-proof agricultural planning.

1 Introduction

In a short debate that took place before the Christmas break in 2022, a motion was adopted by Members of Parliament of CU and CDA,[1] which considered that under the influence of climate change, Dutch agriculture may gain importance as food producer within Europe. The motion requested the Dutch government

> 'to have an independent explanation of the consequences, opportunities and threats of climate change for agriculture and horticulture and the possible significance of this for strategy and policy regarding future food production in the Netherlands and the European Union'.

The latest IPCC ARC6 report (IPCC, 2023) indicates that as a result of further global warming, the southern, warmer climate is shifting northwards. This may eventually make it possible to grow crops in the Netherlands that are currently grown in southern Europe. It may also mean that crops will eventually no longer be viable in the countries concerned, such as Spain, Italy and/or France because of insufficient water available or heat and drought. The Netherlands may then become a more suitable region for growing currently typical Mediterranean crops such as grapes for wine, olives for olive oil or durum and soft wheat. Or the Dutch agricultural sector may achieve higher yields in current crops compared to southern countries, such as onions, potatoes, sugar beet. In short, climate change could well provide the Dutch agricultural sector more comparative advantages compared with southern EU member states.

At the same time, however, the Netherlands will also notice the effects of increasingly extreme weather events which can negatively impact agricultural yields. Moreover, the Dutch agriculture sector is faced by environmental concerns and pressure from society demanding for a transition towards more sustainable production practices (e.g. Hoes and Aramyan, 2022; OECD, 2023). This limits options to expand or intensify agricultural production and requires Dutch farmers to invest in new technologies and innovations to reduce negative effects on the environment. Possibly, then, the agricultural sector in other countries can better anticipate further climate change than in the Netherlands, perhaps not the southern countries, but the countries surrounding the Dutch climate zones such as Germany and Poland.

In recent years, much knowledge has been acquired about risks, bottlenecks and opportunities arising from climate change for agriculture in the Netherlands, but mainly from a biophysical perspective with an emphasis on consequences for physical yields, crop management, crop choice and choice of breed (e.g. Verstand et al., 2022; Ruijs and Splinter, 2019). However, the adopted motion in the Dutch parliament also seems to explicitly ask about the economic consequences of climate change, and the possible consequences for the comparative advantage of the Dutch agricultural sector arising from shifting production zones in Europe.

[1] Motion Grinwis and Boswijk, Kamerstuk 36 200 XIV, nr. 114, 2022.

2 Research objective and approach

This study explores the broad impacts of climate change and socio-economic drivers on EU agriculture and what the implications are for competitiveness of the Dutch agrifood supply chains. The main research question that will be answered by this study is formulated as follows:

> 'What are the medium-term (2050) implications of shifting production zones in Europe due to climate change for the competitiveness of the Dutch agriculture sector?'

Competitiveness is a multifaceted concept that is extensively discussed in the literature (e.g. Krugman, 1994; Lee and Karpova, 2018), without consensus on its definition and ways to measure it. Competition can be analysed at the level of a sector or country, or at the firm level using microeconomic data. Throughout the report, agricultural competitiveness will refer to 'the ability to sell products that meet demand requirements (price, quality, quantity) and, at the same time, ensure profits over time that enable the sector to thrive on the domestic or international market'. Two impact indicators to measure competitiveness at sector level often used in literature are total factor productivity (TFP) and agricultural trade imports and exports (Beck et al., 2024).

The study will focus on a number of key crops in the cultivation plan of the average Dutch arable farmer, such as onions, wheat, potatoes and sugar beets, but also on livestock products, and looks at the potential for the Netherlands to grow more legumes and other protein-rich crops. The study investigates the medium-term effects of climate change on agricultural production in Europe and the Netherlands, using literature (conducting quantitative scenario analysis is beyond the scope in this study) to assess the potential effects of shifting climate zones for competitiveness of the Dutch agriculture sector in the medium term (2050). Both literature and expert views are combined into a SWOT analysis to identify the main strengths, weaknesses, threats, and opportunities for the sector. Finally, from the opportunities section in the SWOT a future pathway is envisioned with several adaptation strategies which we foresee developing in the Netherland in the near future.

These adaptation strategies refer to a plausible and strategic direction for the future development of Dutch agriculture, based on the integrated analysis of climate change impacts (Chapter 5) and the SWOT segments outlining socio-economic dynamics and consumer preferences (Chapter 6). Each adaptation strategy outlines how Dutch agriculture could adapt to emerging risks, leverage existing strength, and respond to new opportunities while supporting European food security and sustainability goals. We foresee these adaptations happening in all parts of the Netherlands at different intensities based on regional conditions.

The structure of the report is as follows. Chapter 3 presents trends of European production, consumption and trade of key crops, and highlights the Dutch position in the EU in this respect. Then, climate change impacts on production of key crops grown in the EU are analysed in Chapter 4, whereas Chapter 5 focuses on climate change impact on Dutch agriculture. The SWOT-analysis in Chapter 6 is used to identify the competitiveness of Dutch agriculture. Chapter 7 outlines several adaptation strategies or development pathways for Dutch agriculture to exploit economic opportunities arising from climate change and socio-economic factors. This report will build on Van Berkum et al. (2025) which looked at the effect of shifting production zones under the influence of climate change on food security on a global and European scale.

3 Agricultural production, consumption and trade in the EU: some historical trends and future projections

This chapter highlights key facts and figures of agricultural production and consumption in the EU, focusing on historical trends and future projections paying particular attention to the five focus agricultural products of this study (grapes for wine, wheat, sugar beets, potatoes, and onions) as well as meat and dairy. This chapter furthermore examines the role of Dutch agriculture within the EU context as producer and exporter of agrifood products.

3.1 Production and productivity

3.1.1 The Dutch position in EU's agricultural production and productivity levels

The EU is a major agricultural producer, with a diverse farming sector that plays a vital role in both its economy and global food supply. Agricultural land (including natural grassland) accounts for almost half of the European territory (48%). Between 2015 and 2024, the overall value of agricultural output in the EU increased from approximately €391bn in 2015 to around €537.5bn in 2023 (Figure 3.1).

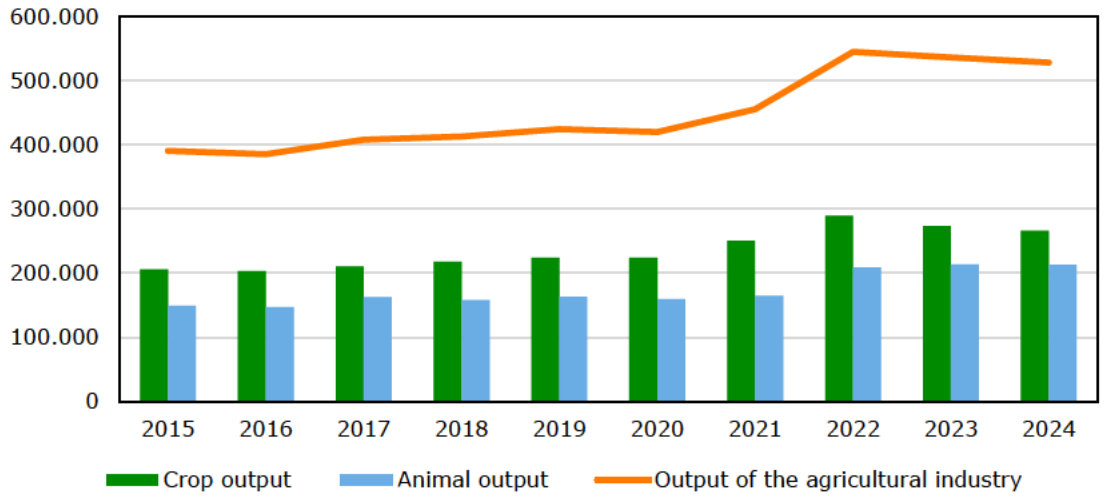

Figure 3.1 *Output value of the EU agricultural industry, million euros. Note: Figures for 2024 are estimates*
Source: Eurostat (aact_eaa01).

A little more than half (50.4%) of the value of the total output of the EU's agricultural industry in 2024 came from crops (€266.8bn), within which vegetables and horticultural products, and cereals were the most valuable crops (see Figure 3.1). Two-fifths (40.2%) of total output came from animals and animal products (€213bn), a majority coming from milk and the pig meat sector. Agricultural services and inseparable non-agricultural activities contributed to the rest (9.4%). The leading contributors to this figure were France, accounting for around €103.8bn (roughly 19.3% of the EU total), followed by Germany with €71.6bn (13.3%), Italy with €71.2bn (13.2%), Spain with €63.8bn (11.9%), and the Netherlands with €41.3bn (7.7%). In the EU context, The Netherlands produces more than proportionally vegetables, potatoes and

milk.[2] Table 3.1 lists the key agricultural products in terms of agricultural output values for the Netherlands. These products together represent nearly 42% of the Dutch export value.

Table 3.1 *Key agricultural products of the Netherlands, billion euros and % of total, 2023*

Product	Value (billion euros) and shares (%)
Total agricultural output, of which	35.673
Crop output, of which	57.0%
Cereals (including seeds)	1.3%
Industrial crops	1.8%
Forage plants	6.4%
Vegetables and horticultural products	34.8%
Potatoes (including seeds)	7.8%
Fruits	2.8%
Animal output, of which	22.6%
Cattle	4.9%
Pigs	19.6%
Poultry	2.9%
Milk	19.6%
Eggs	2.9%

Note: Agricultural output is defined as agricultural production value at basic prices, exclusive Agricultural services, outputs and secondary activities.
Source: Eurostat (aact_eaa01).

Over the last 60 years, EU agriculture has transitioned from a growth model based on intensification (use of more inputs) to one driven by productivity growth, thanks to technological improvements and efficiency gains. Productivity is still growing in the EU, but slower than in other countries, and has recently slowed down in nearly all but the new Member States (OECD, 2023). The slowdown in the productivity growth in the EU as a whole is associated with challenges that both the agricultural sector and EU civil society have to face, such as food prices, climate change and loss of biodiversity.

Total Factor Productivity (TFP) is often used as an indicator to measure changes in productivity and competitiveness for a sector. The TFP integrates the impacts of partial productivity indicators, such as land, labour, intermediary inputs (such as fertilisers and animal feed) and capital. Figure 3.2 shows growth in TFP development within the agricultural sector over the last 10 years across the Member States.

[2] This means: whereas the overall agricultural production value in the Netherlands accounts for 7.7% of EU's total agricultural output, shares of Dutch vegetable, potato and milk output values are higher than 7.7% of EU's output values of these product categories.

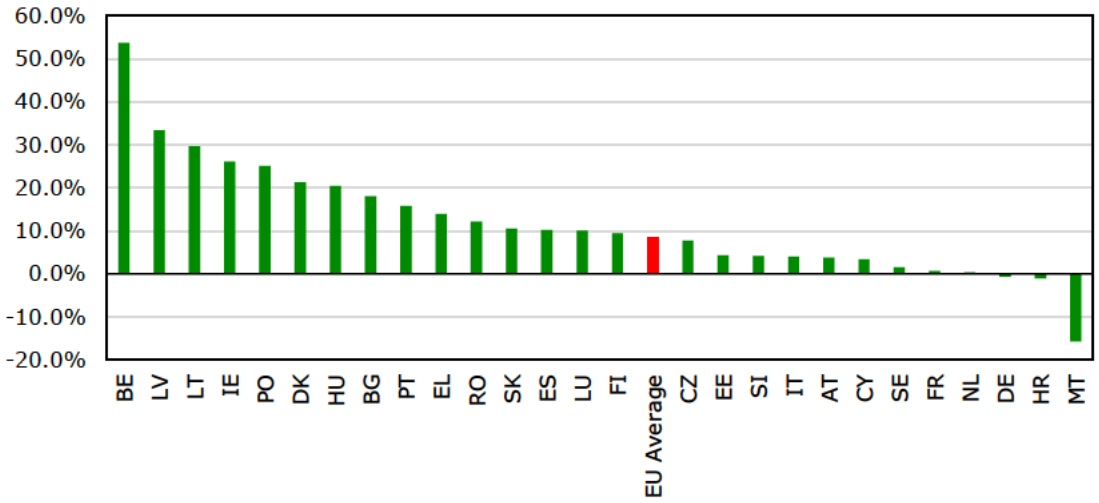

Figure 3.2 *Agriculture Sector TFP Development during the last 10 years in EU Member States (%)*
Source: Farm Accountancy Data Network (FADN).

On average, TFP in the agricultural sector grew by 8.9% in the EU as a whole over the last decade. Belgium achieved the highest TFP growth rate, as well as Ireland, Denmark, Portugal and Greece and a number Member States that have joined the EU more recently (Latvia, Lithuania, Poland, Hungary and Bulgaria)[3]. Some of the Member States with typically high productivity levels, such as the Netherlands and Germany, did not achieve much growth in terms of TFP over the past decade, and, hence, have become relatively weaker in terms of their competitive position vis à vis other Member States. Due to environmental pressure, the Netherlands has invested quite heavily in recent years in environmental measures which possibly has influenced the evolution of farm productivity levels. While some of the more recently accessed Member States have invested heavily in farm modernisation, and thereby realised large productivity gains, having a positive effect on TFP growth rate levels (European Commission, 2023). It is however important to note that large differences of TFP growth exist across different agricultural sectors and within Member States. Finally, productivity growth is also linked to farm size (economies of scale). Growth in the economic size of farms is an indicator for on-farm investments and possibility for scale economies.

3.1.2 Production areas, volumes and yields of the various individual crops, meat and dairy[4]

Vineyards for Wine
The EU has 3.2m hectares of vineyards, with Spain, France, and Italy accounting for nearly 75% of total vineyard area (Vineyards in the EU - Statistics Explained, 2020). The total harvested production of grapes for wine in the EU was an estimated 20.9m tonnes in 2023 (Eurostat, 2023). Although EU wine consumption is expected to decline gradually from 2021 to 2031, international trade is increasingly seen as a means to secure markets for EU wines (European Parliamentary Research Service, 2023).

Wheat
In 2023, France (23.7%), Germany (15.6%), Poland (13.0%), and Romania (7.7%) were the largest wheat producers in the EU (Eurostat). Future shifts in EU agricultural policy may prioritise oilseeds (e.g., sunflower, soy, rapeseed) to reduce reliance on imports, potentially impacting wheat production (Abis, 2023).

[3] Belgium has invested heavily in agricultural modernization in recent years through the EAFRD fund. The level of these investments is comparable to that of several more recently joined European member states. The Netherlands, on the other hand, has invested heavily in environmental measures in recent years due to environmental pressure, which may have affected agricultural productivity. Furthermore, Dutch agriculture is already highly productive, so few additional productivity gains can be achieved.

[4] Production values are taken from Eurostat Economic accounts for agriculture, https://ec.europa.eu/eurostat/databrowser/view/aact_eaa01/default/table?lang=en.

Sugar Beets
The EU, the world's largest beet sugar producer, cultivated 1.5m hectares in 2023, with Germany (28.6%), France (27.7%), Poland (15.4%), and the Netherlands (6.3%) as key producers (Eurostat).

Potatoes
Potato production in the EU is concentrated in a few countries and has been in a long-term decline. Five countries—Germany, France, the Netherlands, Poland, and Belgium—account for two-thirds of the EU's 1.3m hectares of potato production. The Netherlands plays a leading role in exporting seed potatoes, with key markets in North Africa and the Middle East (Eurostat).

Onions
The Netherlands is a major player in onion exports, holding a 15% share of global onion trade. Within the EU, onions are the second most cultivated fresh vegetable, with the Netherlands leading production at 24.2% of total EU output (CBI, 2023).

Meat and dairy
The EU has a sizeable livestock population: at the end of 2023, there were 133m head of pigs, 74m head of bovine animals and 68m head of sheep and goats. A majority of the EU's livestock is held in just a few of the Member States. Spain accounted for about one-quarter of the EU's pig (25.4%) and sheep (23.6%) populations in 2023, while Greece had a similar share of the EU's goat population (25.8%) and France a somewhat smaller share (22.8%) of the bovine population.

Total EU milk production is estimated to be around 155m tonnes per year. The main producers are Germany, France, Poland, the Netherlands, Italy and Ireland. Together they account for more than 70% of EU milk production. The EU dairy herd has been decreasing in recent years as the milk yield per cow has improved. In 2023 there were around 20m cows in the EU, with an average of 7,800 kg of milk produced per cow. A comparison of milk yields of milk specialised farms across the EU shows that milk yields per cow are highest in Spain with 12,510 kg/cow, followed by Estonia (10,295 kg/cow) and Denmark (10,079 kg/cow) (FADN, 2023). The Netherlands is in the sixth place with an average yield of 8,780 kg/cow at specialised dairy farms. The height in yields varies depending on the level of intensity in farming and size of the farms (economies of scale).

3.2 Consumption

Consumer demand in the EU is shifting towards greater sustainability, food safety, and quality. Key trends for the specific commodities include:

Meat and dairy consumption
Meat consumption in the EU is steadily declining, particularly for beef and pork, while demand for plant-based alternatives such as pulses is on the rise (EU Outlook, 2024). This shift reflects a broader trend in consumer preferences, signaling a gradual but meaningful decline in the importance of livestock within European diets. A study by Ammann et al. (2024), which assessed consumer priorities related to meat and dairy products across five EU Member States, found that food safety and animal welfare consistently ranked as the most important attributes, while carbon footprint, food miles, and organic certification were seen as less influential. Complementary research (Protein, 2023) reports that over half of consumers in five European countries now identify as flexitarian, and 46% express growing trust in plant-based alternatives. In the Netherlands, 60% of protein intake comes from animal sources, while 40% comes from plant-based sources (Onwezen et al., 2024). However, the social acceptance of these alternatives is still evolving; some consumers perceive a stigma around plant-based meat substitutes (Malila et al., 2025). Regarding dairy products, at present over half of the global top 20 dairy companies originate in the EU (AHFES, 2022) and in an assessment of consumer trends in five Western European countries there is an increasing number of people choosing plant-based products. The study identifies a steady growth of 3% per year for plant based dairy products (AHFES, 2022). While a complete replacement of animal products by plant-based options is unlikely, there is a slow but steady shift toward more sustainable lifestyles, driven by both consumer interest and external factors such as product availability and EU-level policy. The 2024 EU Consumer Summit, which

convened over 500 stakeholders in consumer policy, emphasised sustainable food labeling as a critical tool for guiding purchasing decisions. If implemented broadly, policies like true cost accounting or sustainability labels could further discourage meat consumption by highlighting the higher environmental and economic costs of animal-based products compared to plant-based alternatives (EIT Food, 2024).

Sugar consumption
EU consumers are reducing sugar intake, lowering demand for high-sugar processed foods. The EU remains a net importer of raw sugar, but these imports are expected to decline (EU Outlook, 2024).

Wine preferences
While overall wine consumption is decreasing, demand for rosé and sparkling wines is growing. Consumers are increasingly seeking quality wines with protected geographical indications and those produced through environmentally friendly methods (European Commission, 2018). Consumers are furthermore also increasingly interested in lower-alcohol and alcohol-free wine options, influenced by health concerns and changing lifestyle choices (EU Wine Market Observatory, 2024).

The EU has an extensive legislative framework around food safety covering food additives, flavorings, contaminants, residue of veterinary medicinal products and food contact materials.[5] From the consumer side the expectations are still strong and there has been a significant increase in consumer awareness about food-related risks. Consumers are now actively seeking products that minimise health risks and prioritise health-conscious production methods (Pettoello-Mantovani, 2022). One study suggests that EU consumers show greater awareness and concern for chemical risks and farm animal welfare and this is likely to influence the likelihood of adopting more sustainable dietary choices (de Boer and Aiking, 2023). This is reflected with goals set out in the F2F strategy whereby member states are encouraged to keep ensuring that chemical pesticides are only used as a last resort in food production.[6]

EU consumption patterns point towards consumers searching for ways of spending less on food purchases, but not at the expense of food quality and safety. EU consumers have concerns about the sustainability of their diets (EU outlook, 2024).

3.3 Trade

The EU is a major global player in agri-food trade, with exports in 2024 valued at €234bn. Key export products include wine, dairy products, cereals, and meat. The United Kingdom, the United States, and China are among the EU's top trading partners in the agri-food sector.

Over the last 15 years, the European Union's agricultural trade has undergone significant transformations, marked by both advancements and challenges that have shaped its current competitive position in the global market. The 2013 CAP reform focused on creating a greener sector that was more equal in farm support and had a bigger focus on regional development and equality.[7] Throughout the last decade the EU has maintained a positive agri-food trade balance and has been the world's largest exporter of processed agricultural products in the world and has entered into bilateral agreements with important trading partners such as Australia, Indonesia and Thailand.[8] However, the balance of primary agricultural products has declined and the trend underscores the growing reliance on imports for essential agricultural inputs such as plant-based proteins, plant protection product and fertilisers, which may leave the EU exposed to shocks on international markets (Beck et al., 2024). Intra-EU export is almost twice the external trade and highlights the interdependence of EU Member States to meet their national demands. Germany, the Netherlands and France are the top three exporters in both intra and extra EU (FoodDrinksEurope, 2023). In 2022, the top 3 categories of export by product value were wine and spirits, followed by cereal preparations and milling products, and dairy products (FoodDrinkEurope, 2023; European Commission, 2024 Monitoring EU agri-food

[5] Chemical safety - European Commission.
[6] EU: Trends - European Commission.
[7] Reform of the Common Agricultural Policy post 2013 - Consilium.
[8] Processed agricultural products in the EU - European Commission.

trade). Table 3.2 lists the key agricultural products in terms of export values for the Netherlands. The products listed together represent nearly 42% of the Dutch export value.

Table 3.2 *Key agricultural export products of the Netherlands, billion euros*

Product	Export value
Dairy and eggs	12.3
Ornamental horticultural products	11.9
Meat	10.7
Cocoa and cocoa preparations	9.9
Potatoes and vegetables	8.9

Source: Jukema et al. (2025).

Intra EU trade may grow in importance as political winds shift and the era of international trade and globalisation which proliferated in the early 21st century is being scrutinised. Beginning with the Global Financial Crisis of 2008, globalisation and liberalisation have stuttered and acceleration in trade has begun to reverse. Import protection and trade barriers were among the first measures taken to protect countries from recession (Baldwin and Evenett, 2009). The ensuing austerity measures (McKee et al., 2012) in Europe followed by Brexit (Clark et al., 2017), COVID-19 pandemic (Shrestha et al., 2020) and the Ukraine war (Steinbach, 2023) have all taken their toll on trust and proliferation of global markets. This has prompted countries to prioritise domestic agricultural sectors, leading to the implementation of tariffs, quotas, and stringent sanitary and phytosanitary standards (EC, 2020; Marti et al., 2021). Despite warnings from the WTO that decoupling the global economy will have overall negative effects on investment, knowledge exchange and a potential drop of world trade by 13% (WTO, 2024), international trade is increasingly being driven by national security concerns and reshoring of supply chains. The future trajectory of international trade is uncertain but it is clear that the EU as the single largest global importer and exporter of goods and services will have to navigate a turbulent international stage and internal political pressure to protect the single market (Baur and Flach, 2023).

Projections on the outlook of the EU agricultural sector to 2035 expect the EU to continue being a net exporter of agri-food products aiding in global food security, and remaining self-sufficient for several commodities such as wheat, barley, meat, dairy products, olive oil and wine, while remaining a net importer for maize and oilseed (EC, 2024). These projections have considered the negative impacts of climate change on yields and production volumes and assume constraints on the availability and affordability of certain agricultural inputs (e.g. plant protection products and fertilisers (EC, 2024:4)). At the same time, results of the projections show an improvement across all environmental and climate indicators included in the analysis with a projected reduction in greenhouse gas emissions, ammonia emissions, and nitrogen surplus (EC, 2024).

Table 3.3 *EU commodity markets: status and trends*

Status and Trends	Commodities
Net exporter	Agri-food products overall; especially: wheat, barley, meat, dairy products, olive oil, wine, table olives
Self-sufficient	Wheat, barley, meat, dairy products, olive oil, wine
Net importer	Maize, oilseeds (e.g. soya), sugar (though import reliance projected to decline)
Moving toward export of	Higher-value goods rather than higher volumes
Trade Trends	Export growth slowing due to global competition and reduced demand in key markets (e.g. China)
Protein trade outlook	EU could increase net exports of proteins, reduce imports due to declining feed demand
Import dependency concerns	Protein-rich feed (e.g. soya), highlighted weakness in scenario modeling

Source: Own table, based on data from EC, 2024 (EU Agricultural Outlook).

4 Impacts of climate change on agricultural production areas in the EU

Europe is the least affected by climate change and will be according to IPCCs future projections (IPCC, 2023). Climate impacts in Europe are leading to shifts in crops from south to north, as the south experiences higher temperatures and less/more irregular precipitation and the growing season in the north is extended. In large parts of southern Europe an increased risk of livestock production is projected as drought may reduce grassland productivity and animal health. The projected increase in rainfall in northern Europe may pose challenges for livestock grazing and harvesting grass, next to challenges of wider distribution of pathogens across Europe.

However, IPCC's latest projections for Europe most likely need to be adjusted as 2024 was the warmest year on record for Europe, with all four seasons being warmer than average, with record temperatures experience in central, eastern and southeastern Europe (Global Climate Highlights 2024 | Copernicus). The past 3 years have seen unprecedented extreme flooding events in Europe, in north west Europe in 2021 and southern and eastern Europe in 2023, while in Denmark 1.6m people were affected by flooding (EEA, 2024). In southern Europe approximately 30% of the population live in areas with permanent water stress and up to 70% in areas with seasonal water stress during the summer, and this number will increase as climate change impacts become increasingly apparent (EEA, 2024). 2022 saw the annual average river discharge across Europe being the second lowest on record, with 63% of river having-below average discharge. This alters salinity gradients and has negative impacts on biodiversity and the spread of invasive species (EEA, 2024).

Climate change is expected to impact both biotic and abiotic stresses on agricultural crops. The occurrence and abundance of pests and diseases are closely linked to climate factors, such as warm and wet conditions, as well as prolonged wet periods. Climate change can lead to an expansion in the geographic range and abundance of pests and diseases, as well as an increase in the number of pest generations per year (Skendžić et al., 2021). While it is clear that the challenges posed by pests and diseases will increase, the specific impacts are not yet fully understood. Simultaneously, there is growing pressure to reduce the use of chemical pesticides. In line with this, the European Commission's Farm to Fork Strategy establishes EU-wide targets to cut the use and risk of chemical pesticides by 50% by 2030, embedding pesticide reduction within the broader objectives of the European Green Deal (EC, 2020). And although the target to halve pesticide use by 2030 was abandoned in 2024, the EC still intends to help reduce the use of harmful pesticide (EC, 2025). This dual challenge underscores the necessity for effective monitoring and innovative solutions in crop management to sustain productivity while also protecting the ecosystem. How climate change can affect production and productivity of different agricultural products is explained in the following paragraphs.

Wine

Climate change is reshaping viticulture. Southern Europe will need to adapt by switching grape varieties and increasing irrigation, while Western and Central Europe may see improvements in wine quality and growing areas (Malheiro, 2010). It is probable that increased temperature and droughts in the future will result in eventual overall loss of viticulture suitability in mediterranean climate countries across southern Europe, while in central and northern Europe, these warming conditions will open the land for more suitable grape cultivating conditions (Droulia and Charalampopoulos, 2021). Future scenario modelling by Moriondo (2013) indicates that the wine growing region shifts are likely to start from 2020 onwards and will happen within the existing territory of wine cultivating countries with the vineyards moving to cooler Atlantic coastal regions or moving to areas of higher elevation relatively close to current regions.

Wheat

Drought and extreme weather reduced cereal harvests in Spain (-38.2%), Denmark (-26.0%), and Sweden (-25.7%) in 2023 (Eurostat, 2024). This shows how vulnerable grain harvest in Europa is to extreme weather. Highly cited papers (Trnka, 2014) indicate that with a warming climate, central and north-western European wheat growing areas are likely to suffer less from increases in adverse event occurrence compared to the rest of Europe. But as a whole the majority of growing areas have increased risk of single adverse

events and subsequently crop failure, with tradeoffs between wetter colder conditions in northern regions and limitations due to water availability and heat stress in southern regions. Five key studies simulating the possible effect of climate change in Europe, predict an increase in unfavorable growing conditions for wheat particularly concerning heat stress (Le Gouis, 2020).

Sugar Beets
Yield increases due to future climate change are expected in northern Europe of around 1 tonne/ha of sugar for 2021-50, but similar decreases are expected in drought prone areas of France and Belgium (Pidgeon, 2004). Modelling of future climate change scenarios on sugar beet cultivation find that even the worst scenarios did not find any dramatic changes in beet root emergence (Lamichhane, 2019). Drought indirectly impacts the attraction and performance of parasitoids on plants, which may result in lower predation pressure on aphid populations. This, combined with ed aphid performance, may lead to aphid outbreaks, which could further weaken drought-stressed plants (Rahman et al., 2025).

Potatoes
Warming temperatures are making Southern and Eastern Europe less suitable for potato farming, increasing reliance on Northwestern Europe (Goffart, 2022). Potato yields are likely to be negatively affected under all future warming scenarios but the changes to yield will be minimal or even positive in high altitude areas while having a stronger negative effect at lower altitudes (Hijmans, 2003). Higher temperatures in growing areas at higher latitudes can extend the growing season and increase potential potato yields. However, this also raises the risk of pests and diseases, which thrive and multiply faster in warmer conditions. Milder winters result in more tubers surviving as ground keepers, enhancing the spread of diseases like late blight (caused by Phytophthora infestans) (Haverkort and Verhagen 2008).

Onions
Warmer temperatures with CO_2 increase will increase onion yields in Europe but this in negated due to the increase in extreme weather events (van Tilburg, 2022). Drought is the biggest factor in climate impacts affecting onion yields (Sansan, 2024; Nurga, 2020; Ghodke, 2018; Shock et al., 1999). Overall there is no major threats to onion production in the observed literature. Warm and humid during summer increase the risk of fungi infecting the leaves leading to yield reduction (Schaap et al., 2009).

From the above it appears that in general no major shifts in crop cultivation patterns in the EU are expected as a result of climate change. Winegrapes cultures will remain mainly in the current major production countries and for other arable crops discussed the suitability of southern and eastern Europe for producing them becomes less but no dramatic shifts are expected either. In general it is expected that disease pressure will become much higher due to the average higher temperatures and to the alternation and increased intensity of (too) dry and wet periods.

An increase in disease risks also leads to more uncertainty about yields. Farmers could insure themselves against yield losses resulting from extreme drought or wet spells, or other weather events due to climate change. Some studies attempt to estimate the costs of these risks and arrive at billions of euros in potential crop losses. For example, the fi-compass study (EIB Advisory; EC, 2025) estimates that the EU27 agricultural sector loses an average of €28bn each year from extreme weather made worse by climate change. This amount is around 5% of EU's current agricultural production value. Depending on the RCP warming scenario (+2 C or more), up to 2050 the loss may amount to around 10% of the current production value in the EU. These EU-wide averages incorporate significant variations by region, crop and peril. As for regional differences, the highest estimates of losses are estimated in the large production countries France, Germany, Italy and Spain (which is understandable given their contribution to the production value in the EU). If the estimated amount of production value loss is expressed as a share of Gross Domestic Product (GDP), the greatest consequences will be borne by Hungary, Romania and Bulgaria, followed by Greece and Croatia (EIB Advisory; EC, 2025).

5 How Dutch agriculture will be affected by climate change

Up to 2050, climate change will pose both opportunities and risks for Dutch agriculture. While rising temperatures may extend the growing season and benefit some crops if warming stays below 2°C, these gains are unlikely to offset broader losses (IPCC, 2023). Heatwaves, droughts, and erratic rainfall are projected to reduce yields and crop quality, particularly on sandy and clay soils. Earlier growing seasons may also increase frost risk and disrupt pollination. Milder winters are expected to raise pest and disease pressures, while salinisation and groundwater depletion threaten coastal agricultural zones (IPCC, 2022). The KNMI'23 climate scenarios indicate that summers in the Netherlands will become drier and hotter, with more frequent heatwaves and increased evaporation from soils, thereby raising the risk of prolonged droughts and water stress in agricultural regions, especially on sandy soils (KNMI, 2023). At the same time, intensifying rainfall in winter and during summer storms could lead to localised crop damage and soil erosion (KNMI, 2023). These extreme events and their erratic nature will result in yield loss and quality decline, and create operational challenges for farmers. Wetter winters and warmer and drier summers will further elevate pest and disease risks, as milder conditions allow for higher pathogen survival during the off-season. Wetter conditions in spring can complicate the sowing of winter wheat. Fusarium (a fungal disease) may decline during the expected drier summer period, potentially benefiting crop production and quality. Additionally, wet weather during potato planting and harvesting can reduce yields and increase costs, while intense rainfall raises the risk of tuber decay. Rising temperatures may increase second growth in potatoes, and conditions may become more favourable for Pectobacterium carotovorum, a bacterial pathogen. Conversely, one current challenge late blight (Phytophthora infestans) may decline as drier conditions reduce the need for fungicide spraying (Schaap et al., 2009).

To address these challenges, Dutch agriculture is embracing a range of adaptation strategies. Nature-based solutions, such as rewetting peatlands, nature-inclusive farming, and integrating green-blue infrastructure are increasingly used to enhance water retention, restore soil function, and reduce vulnerability to climate extremes (Verstand et al., 2024). At the same time, technological innovations in protected horticulture offer climate-controlled growing environments that buffer against droughts, floods, and pests. The transition toward climate-neutral, year-round production is supported by developments in LED lighting, substrate cultivation, biological pest control, and sustainable heating solutions (Ruijs and Splinter, 2019). These strategies not only improve resilience but also contribute to position Dutch agriculture to meet growing demand for healthy, safe, and sustainably produced food. Table 5.1 below summarises the major risks associated with climate change and how the Dutch agricultural could possibly adapt to those risks.

Table 5.1 *Risks arising from climate change affecting agricultural production in the Netherlands and some suggested adaptation strategies (not exhaustive)*

Risks	Impact	Adaptation strategies
Extreme and unpredictable weather	Reducing yields, reducing soil quality	Crop diversification, improved irrigation techniques, and soil conservation practices
Rising average temperatures	Affecting suitability of crop to grow	Diversifying crops, using precision agriculture techniques, implementing sustainable farming practices, improving water management
Increasing occurrence of pests and diseases	Reducing yields	Diversifying crops, using climate-resilient varieties, implementing integrated pest management (IPM), improving soil health
Salination and groundwater depletion	Reduced availability of freshwater	Water conservation and water harvesting measures, efficient irrigation systems, drought-resistant crops
Sea level rise	Increasing salination reduces yields and usability of agricultural land in coastal zones	Protecting farm land (building flood defenses, elevating infrastructure), improving water management, diversifying crops and livestock
Increasing CO2 concentration	(potentially) increasing yields (in some crops), reducing nutritional quality (in many crops)	changing land and cropping practices, developing improved crop varieties, optimising water and nutrient management

Supported by the Netherlands' CAP Strategic Plan and a number of other national strategies—such as the Action Programme for Climate Adaptation in Agriculture and regenerative farming initiatives—the collective efforts reflect a long-term commitment to transitioning toward a more climate-resilient, diversified, and sustainable agricultural system. In open-field arable farming, cereal grains and legumes are projected to play a more important role due to their lower environmental footprint and contribution to soil health and carbon sequestration, while intensive crops like potatoes and sugar beet may decline in relative importance (Verstand et al., 2022). In parallel, the greenhouse sector will increasingly prioritise high-value crops such as soft fruits, leafy greens, herbs and pharmaceutical crops like cannabis and vanilla, supported by technological innovations in protected horticulture, including LED lighting, substrate systems, and biological pest control (Ruijs and Splinter, 2019). At the same time coastal salinisation and drought related pressures will likely lead to increased cultivation of salt tolerant crops in vulnerable regions (NEM, 2021). This transition is not only driven by biophysical and market shifts but also by tightening EU environment regulations such as the European policy ambitions to reduce nutrient losses, and new business models emphasising circular agriculture, multifunctional land use, and carbon credit schemes (EC, 2025). These combined forces are reinforcing a shift away from volume maximisation toward resilience, circularity, and value-added production.

By 2045, land previously dedicated to agriculture will face increasing pressure from urban expansion, with projections indicating a need for up to 17,000 hectares of new residential area to be built around the Randstad region (PBL, 2019). In addition, the energy transition will demand substantial acreage for wind turbines, solar farms, and grid infrastructure, especially in peripheral agricultural zones where land is less expensive (PBL, 2019). Furthermore, ongoing and future flood protection efforts under 'Ruimte voor de Rivier' programme will continue to claim land for riverbed widening and floodplain restoration, reducing arable availability in vulnerable regions like Arnhem-Nijmegen.[9] These combined claims will likely accelerate consolidation and regional differentiation of agriculture, with higher-value glasshouse cultivation intensifying near urban zones and open field farming migrating to areas with fewer spatial conflicts. Therefore, which crop to grow will not only be shaped by climate change impacts, policies and markets, but also by the new reality of contested multifunctional landscapes.

[9] Ruimte voor de rivieren.

6 Economic opportunities and obstacles for the Dutch agricultural sector to benefit from climate change impacts (SWOT)

The European agricultural sector faces significant climate-related challenges; climate risks require strategic adaptation and potentially significant investments to make the sector more resilient to climate change impacts. In this section we will reflect on how the Dutch agricultural sector can position itself to maintain its competitive position in the EU. We do this by defining the strengths, weaknesses, opportunities and threats (SWOT) for the Dutch agrifood sector.

Strengths

Dutch agriculture benefits from a strategic geographical position, advanced infrastructure, and strong integration with the EU market, enabling efficient trade and distribution. One of the most significant strengths is the Netherlands' leadership in technological innovation, including applications in the agricultural and horticultural sector such as precision farming and greenhouse technologies, which enables farmers to optimise production despite changing climate conditions. The sector is also characterised by a strong processing industry with companies active in different countries (multinationals) part of which are owned by farmers (e.g. animal feed, potatoes, dairy, meat, finance). Additionally, the Netherlands' well-developed infrastructure for transportation, storage, and processing ensures efficient distribution of agricultural products both domestically and internationally, further supporting its global trade presence. The port of Rotterdam and Amsterdam Schiphol are well recognised as international transport hubs, alongside the importance of international railway connections for international freight loaded (Corselli-Nordblad et al., 2022). Dutch agriculture is also highly diversified, encompassing horticulture, dairy, and livestock, which provides the flexibility needed to adapt to changing environmental conditions. Strong research and development capabilities, driven by Dutch universities and agricultural institutes, foster the advancement of sustainable farming practices and climate-resilient crops, helping the sector adapt to new challenges. Finally, as one of the largest agricultural exporters in the world, the Netherlands benefits from its position as a key trade hub, which helps mitigate risks from regional shifts in production zones and strengthens its access to international markets.

Weaknesses

Despite its strengths, Dutch agriculture faces several weaknesses that could hinder its ability to fully adapt to shifting production zones due to climate change. One major vulnerability is its susceptibility to extreme weather events, such as floods, droughts, and storms, which can disrupt agricultural production and supply chains (KNMI, 2023). The sector also heavily relies on global trade, making it vulnerable to disruptions from changes in international markets or geopolitical tensions. Another potential weakness is the idea of lock-ins; these come in the form of financial, technical and cultural aspects. Farmers rely on financing from government and other funding bodies which decide what crops or growing methods are used based on what the funding is provided for. In the case of multiyear or longer funds this potentially locks the farmer into growing specific crops or producing in certain ways or using certain methods which lends itself to the technical aspect. The cultural aspect comes from the farmers themselves, as farming is considered a proud tradition that goes back for generations for some farming families they may have developed an affinity or preference for a certain crop, or livestock which economically and financially may not be the best choice any longer or in the future but this cultural lock-in persists the continuation of the status quo. Research such as Barnes et al. (2022) demonstrates lock-ins in agriculture, pointing out the biggest determining factor of adopting new farming approaches is past activities. Hence, 'path dependency' creates the so called lock-in effect we discuss here. This highlights the need that a tailored approach is required for adopting new technologies and more effort should be dedicated to helping farmers transition out of these path dependencies. Additionally, the Netherlands is densely populated and thus has relatively limited agricultural land, and with climate change potentially reducing the area suitable for agricultural purposes

(climate change may reduce soil fertility, see Eurofins Agro 2020),[10] this scarcity places increased pressure on existing farming systems and prices of farmland. Also due to land use change of agricultural land, total agricultural area declines: for instance, between 2013 and 2020, 244 square kilometers of agricultural land was lost main due the increase in built-up areas.[11] Environmental regulations implemented to reduce environmental pressures of current intensive agricultural practices may limit the ability to scale up production in response to climate shifts or growing market demands. Moreover, intensive farming practices have led to concerns about soil degradation and nutrient imbalances (RVO, 2016), which, when compounded by climate change, could negatively affect crop yields and overall agricultural productivity.

Opportunities

Shifting production zones due to climate change also present several opportunities for Dutch agriculture (EC, 2023). One key opportunity is the potential to shift to new crops that are better suited to the changing climate, such as drought-resistant varieties or new types of fruits and vegetables, which could diversify agricultural outputs. In addition, among European consumers but also beyond there is a growing demand for sustainably grown and produced food, and Dutch farmers, who are working towards more environmentally friendly practices, are well-positioned to meet this demand. Both developments could create new markets for Dutch agricultural exports, particularly in regions where local production has been negatively affected by changing climate patterns. The emerging carbon credit markets (European Commission, 2021) also present an opportunity for Dutch farmers to earn income by adopting climate-smart farming practices that reduce emissions. Finally, further investment in it greenhouse farming, an area in which the Netherlands is already a global leader, could offer year-round, climate-controlled production, providing a stable and efficient way to meet growing food demands despite climate uncertainty.

Threats

Dutch agriculture also faces several significant threats as a result of climate change. One major threat is that climate change could lead to water scarcity, especially in southern parts of the country, as altered rainfall patterns and higher temperatures threaten the viability of water-intensive crops and livestock (Van Der Wiel et al., 2024). Water safety is also an issue for the Netherlands; the sea level rises in all KNMI climate scenarios. This may increase salination that may become a bigger problem in the lower parts of the Netherlands: during dry, hot summers, a lot of fresh water evaporates, giving seawater and brackish groundwater the opportunity to flow up into the soil and surface water. There are also risks associated with new regulatory and policy changes, as the European Union adapts to climate and environmental crises. These could, for instance, include restrictions on water usage, obligations to reduce GHG emissions, or other environmental factors that may limit production capacity and/or increase the costs of current farming practices. Moreover, the loss of biodiversity, such as changes in ecosystems that impact pollinators (IPBES, 2016) and soil health, could result in decreased agricultural productivity and increased food security risks. Another threat is that Dutch sectors will lose the competition with those in other European countries where farmers apply adaptation strategies more quickly/effectively than farmers in the Netherlands. Lastly, the shifting production zones across Europe could lead to market volatility and fluctuations in food prices. If the Dutch agricultural sector cannot anticipate or respond to these, profitability of the Dutch agricultural exports could be undermined.

[10] https://www.eurofins-agro.com/nl-nl/klimaat-en-bodem#:~:text=De%20afgelopen%20twee%20jaar%20hebben,(of%20juist%20meer)%20vocht.

[11] Built-up area expanding at the cost of farmland | CBS.

7 Adaptation strategies to climate change: how Dutch agriculture may use economic opportunities in a changing world

In this report we have outlined the position of the Dutch agriculture in a European market and international trade context. Climate change may impact that position as it will continue to affect agricultural yields, production levels and farmers' crop choices. Climate models expect a northward migration of relevant climate zones for many important crops such as wheat, grapes for wine and potatoes (Ceglar et al., 2019). This could lead to possible crop production increase or the introduction of crops that were previously not grown in the Netherlands, but climate change also entails increased risks of disease and pests or a threat to the freshwater availability, which will also influence the farmer's choice which crop to grow. However, climate change is not the only factor that determines which crops can be grown in the Netherlands. Economic opportunities play a major role, determined among others by trade opportunities and consumer preferences. The Netherlands has a competitive agricultural sector. This highly productive and integrated sector in international supply chains has benefited from world leading innovation, research and investment to carry it forward into each new strategic direction. The question of how to benefit from shifting production zones due to climate change is, however, not a matter of a simple matching exercise where crops are mapped to suitable regions but also demands a reflection of how wider sociopolitical contexts are shaping the production of food, and the adaptability of the Dutch agrifood sector to changing circumstances in order to maintain a leading role in the European market.

This chapter reflects on the previous chapters and outlines a number of development paths in which different adaptation strategies are combined in response to climate change. The adaptation strategies respond purposefully to expected (risks of) climate effects and socio-economic trends, including changing consumer demand, spatial constraints and environmental pressure. These strategies can be implemented with different intensities, and also simultaneously differently in different regions in the Netherlands, because the consequences of climate change, spatial claims and environmental pressure are not the same everywhere in the Netherlands. However, these climate adaptation strategies will most likely take place in a context in which precisely these socio-economic trends will strongly determine the structure and size of the Dutch agrifood sector.

The Netherlands is a small, densely populated country with many spatial claims and environmental problems. Spatial claims of nature restoration, housing needs, energy transition, water buffering and flood protection literally give agriculture less space to produce. To comply with (international) agreements to combat climate change (e.g. the Paris Agreement 2015) and EU and national regulations to preserve nature, enhance biodiversity, reduce CO_2 emissions and improve water and soil quality, the sector will have to become less intensive (in input use) in the future and possibly even reduce livestock numbers. Under pressure from these external factors, it is very conceivable that Dutch agriculture will be smaller in the near future, both physically (i.e. number of companies, animals and hectares) and economically (turnover and added value) than it is now. In that light, the climate adaptation strategies for the agricultural sector proposed below are mainly aimed at maintaining or increasing the added value in the sector. Below, we outline four adaptation strategies that differ in their goal and outcome, but more are conceivable.

Potential adaptation strategies

1. **Strengthening climate-resilient food supply including investments in trade and logistics**
   Climate change increases yield uncertainty, especially in Southern and Eastern Europe. This affects the supply of certain crops, such as onions, potatoes and cereals in those regions. The Dutch agri-food sector can leverage its international business and distribution network, and its advanced logistics and storage systems, to act as a stabilising factor on the EU food market. Therefore this adaptation pathway is about keeping the Netherlands competitive in the production of basic food crops and increasing its market share in times of climate induced shortages. The Dutch primary sector can respond by developing flexible production systems, which can adapt to environmental conditions and market trends. For example, modular greenhouse designs allow for rapid reconfiguration to grow different crops or to adapt to market demand. Open field crops will need to adopt (more) climate-resistant cultivation practices (see Table 5.1 in Chapter 5 for suggestions). The Netherlands can strengthen its role as a climate-adaptive supplier of key crops, especially in periods of regional climate stress. However, scaling up cultivation flexibility requires parallel investments in value chain infrastructure, processing, labour and marketing skills, and deliberate policies to support these transitions (see also WUR, 2023; Berkhout et al., 2018). After all, the ability to change cultivation patterns or introduce new cultivation systems does not guarantee that the associated value chains, including processing, storage and transport, will automatically follow, but requires deliberate coordination within value chains, and between public and private investments. In order to cope with the challenges that arise due to climate change, the Dutch government has developed an Action Programme for Climate Adaptation in Agriculture. This Action Plan describes how the agricultural sector can prepare for extreme weather and other risks associated with climate change (Ministry of Agriculture, Nature and Food Quality, 2020).
2. **Farming within limits: Strengthening Dutch sustainability through spatial efficiency**
   This pathway helps the Netherlands maintain high-value, reliable output within strict land and environmental limits, something few EU Member States are currently equipped to do at scale. Given the spatial claims for, among other things, energy transition, biodiversity restoration, urban expansion and water buffering, the land available for agricultural purposes is expected to decrease significantly within ten to twenty years. As a result, agriculture will take place in a landscape that is more multifunctional in nature. These landscapes must also be able to withstand expected biophysical pressures resulting from climate change, such as salinisation or drought stress. This will result in agriculture that, in keeping with multifunctional landscapes, produces, intensifies and diversifies sustainably. Marketing is aimed at consumers who are willing to pay a premium for sustainable and climate-resilient food products. The current Dutch strengths, such as intensive cooperation between sectors and market development through knowledge exchange between companies and research, will continue to be used. This path builds on the existing export strengths (network and positions) of the Netherlands and responds to the increasing importance that European food consumers attach to sustainability (see also Section 3.2). This strategy ensures that the Dutch agricultural sector maintains an economic perspective with sustainable production methods and at the same time adapts to the consequences of climate change, but also contributes to climate mitigation and reduction of environmental pressure.
3. **Scaling controlled-environment agriculture as climate resilience infrastructure and Dutch knowledge expertise**
   Greenhouse horticulture is already a strong competitive asset for Dutch agriculture, and it can also serve as a core adaptation strategy. Investing in circular, low-emission greenhouse systems can secure year round, high quality production in a future where a transition from fossil to renewable energy is necessary to cope with climate change. This pathway highlights that Dutch competitiveness in greenhouse horticulture is a combined package not just about the technology (hardware) but also the cultivation and organisational expertise (software and orgware) the Netherlands offers to other countries. Controlled cultivation in greenhouses can mitigate much of the problems faced by the Netherlands due to climate change such as soil salinisation, drought, pest and diseases and frost. Greenhouses offer protection from erratic rainfall and can reduce the risk of tuber decay or fungal pathogens that thrive in increasingly wet spring and autumn conditions. The Netherlands can leverage its expertise in greenhouse construction and vegetable growing techniques. By strategically integrating with urban food systems, and offering not only nutritional produce but also renewable energy to urban areas, the greenhouse sector can contribute to decarbonisation and food security goals while reducing the pressure on land availability. Investments in greenhouses integrated with waste heat recovery, rainwater harvesting, and solar energy grids help to reduce resource extraction pressures.

4. **Scaling high value crop production via leguminous plant proteins**
   While yields of large cultures such as maize and sugar beets are becoming more uncertain due to climate change, there is also the growing demand for vegetable proteins. The Netherlands is well positioned to lead in this emerging market due to its advanced agri-tech infrastructure, high automation, skilled workforce, and ability to efficiently scale production and distribution of high-value leguminous crops across the EU, but success depends on substantial investments in breeding to increase production per hectare in the Netherlands. The growing human consumption for plant-based alternatives to meat and dairy means that legumes, such as lentils, chickpeas, quinoa, soy and chia, can be an attractive alternative to grains or sugar beets for farmers. At the same time, livestock farming is likely to decline in the future due to the ongoing nitrogen crisis in the Netherlands, potentially reducing animal protein consumption (as meat and dairy become more expensive) and encouraging the conversion of grassland to arable land. However, opportunities for land repurposing should be considered in light of competing spatial claims, including for housing, energy infrastructure (e.g. solar and wind energy) and nature restoration initiatives. Legume cultivation can also play a role in achieving the Netherlands' climate goals and solving the nitrogen crisis. Legumes such as lentils and soy are more tolerant to heat and moderate drought than traditional arable crops and may prove to be more adaptable to the hotter, drier summer conditions projected for the Netherlands. This makes legumes a strategic crop choice in light of rising summer temperatures and projected drought conditions, especially in regions with sandy soils vulnerable to water stress. Due to the benefits of nitrogen fixation inherent in legume plants, the Netherlands can reduce the need for synthetic fertilisers and improve soil health and fertility. The incorporation of legumes into crop rotations of wheat for example is already well established in the Netherlands. The growing capacity of producing these plant proteins while meeting consumer demands can also help offset the reliance on foreign imports of livestock feed such as soy and thus support a lower-input livestock system in the Netherlands. All these outlined possibilities do require significant investments to make the production of legumes in the Netherlands a viable business case.

8 Discussion and conclusions

This report has explored how climate change, evolving consumer demands, and spatial pressures are reshaping the outlook for Dutch agriculture. Using a SWOT analysis, we have identified adaptation pathways that align Dutch agricultural strengths with future European food security needs. These adaptation pathways outline adaptation strategies that recognise the Netherlands comparative advantage in technology, trade infrastructure, and controlled-environment agriculture, but also emphasise the increasing limitations imposed by biophysical risk and spatial competition.

A core finding is that climate change impacts, though most likely less severe in the Netherlands than in many other parts of Europe, will nonetheless place significant pressure on the resilience and flexibility of agricultural systems in the Netherlands. Soil degradation, salinisation, heat and drought stress on sandy soils, pest and disease pressures from milder winters, and disruptions to planting and harvesting due to rainfall variability all present growing operational risks. These changes must be considered not only as agronomic challenges, but also as constraints that shape the economic and spatial viability of crop production.

Our study reveals that climate change is still insufficiently factored into long-term agricultural planning in the Netherlands. While sustainability and circularity receive increasing policy attention, the strategic integration of future climate variability, especially extreme weather risks, into land use, infrastructure investment, and agri-food policy remains fragmented. Dutch policymakers should urgently ensure that climate adaptation is mainstreamed across planning and policy frameworks, particularly in view of the Netherlands' role as a key food supplier in the EU, which wants to limit its dependence on imports from third countries in response to, among other things, geopolitical tensions and climate change.

Based on the work of this SWOT we have a few takeaways for the competitiveness of Dutch agriculture. As described in the strengths section, the Netherlands is well-positioned to remain a leading agri-exporter but it cannot rely on its current advantages to continue its relevance and status into the future. There will be a need for innovation and transition but the Netherlands is equipped with the tools to do it, more so than other European countries. Climate change will reshape Europe's food production landscape, creating both threat to Dutch competitiveness but also new market openings. To capitalise on new opportunities and market openings, innovation and adaptability will be the cornerstone of maintaining leadership, particularly through high-tech farming, climate-smart crops, and sustainable practices. Increasing resource constraints in e.g. land, water, and biodiversity as well as tightening regulations require a proactive shift toward efficiency and circularity. The Dutch agrifood sector must strike a balance between ambitions to be an important global producer and exporter of agricultural products with resilience at home, navigating shifting trade flows, consumer expectations, and environmental pressures.

The adaptations described in Chapter 7 are pathways the Dutch agrifood sector could pursue for future development and to some extent are already happening in certain areas and intensities. These adaptation pathways envision a way the Netherlands can maintain competitiveness in light of shifting production zones due to climate change. They include the following four strategies: strengthening the Dutch role as a stabilising force in EU food supply, optimising production within multifunctional landscapes under spatial constraints, advancing controlled-environment agriculture for resilience, and shifting toward high-value crops like legumes aligned with changing consumer demands and environmental goals. Together, these strategies underscore how Dutch agriculture can leverage its existing strengths while adapting to the evolving climate and policy context. If no pathway is followed, the Netherlands may risk losing its competitive position in the future.

Furthermore, this report identified a significant gap in recent, context-specific research on the biophysical impacts of climate change on Dutch agriculture. Much of the existing literature, including projections and adaptation framework, still draws heavily on foundational studies form the early 2000s (among others Van Heel, 2005; Wolf and Van Oijen, 2003; Pidgeon et al., 2004; Schaap et al., 2011; Haverkort and Verhagen, 2008; Schaap et al., 2009). Although models and scenarios can be updated, without new data and models that capture evolving risks, efforts to future-proof Dutch agriculture may be built on outdated assumptions.

In this regard, we call for renewed investment in applied climate-agriculture research that can inform national and regional adaptation strategies. There is a need for modern research to understand compounding risks (e.g. drought plus disease outbreaks), and assessing the thresholds at which climate change could force structural shifts in land use. Strengthening this knowledge base is essential to ensure that the Netherlands remains not only a global agricultural leader, but also a climate-resilient and socially responsive food system actor into the future.

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Appendix 1 Motion Grinwis/Boswijk (in Dutch)

Kamerstuk 36 200 XIV, nr. 114

GEWIJZIGDE MOTIE VAN DE LEDEN GRINWIS EN BOSWIJK TER VERVANGING VAN DIE GEDRUKT ONDER NR. 103

Voorgesteld 20 december 2022

De Kamer, gehoord de beraadslaging,

constaterende dat klimaatverandering grote impact gaat hebben op de voedselvoorziening en landbouwpraktijk wereldwijd en ook in Europa, onder andere door droogte en verzilting, piekbuien, het ongeschikt worden van grote gebieden voor landbouw in Zuid-Europa en het verschuiven van klimaatzones naar het noorden; overwegende dat dit deel van Noordwest-Europa, inclusief Nederland, mogelijk relatief aan belang wint in de voedselproductie, zoals we dit jaar zagen in de opbrengsten van producten als consumptieaardappelen en uien, die door de droogte elders in Europa tegenvielen, maar hier ondanks de droogte en dankzij zoetwaterbeschikbaarheid relatief hoog waren;

verzoekt de regering onafhankelijk uiteen te laten zetten wat de gevolgen, kansen en bedreigingen zijn van klimaatverandering voor de land- en tuinbouw en de mogelijke betekenis daarvan voor strategie en beleid inzake de toekomstige voedselproductie in Nederland en de Europese Unie, en gaat over tot de orde van de dag.

Grinwis en Boswijk

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REPORT 2025-017-2

The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 7,700 employees (7,000 fte), 2,500 PhD and EngD candidates, 13,100 students and over 150,000 participants to WUR's Life Long Learning, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.

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