

Technological innovation as a pillar of ensuring food security: the Netherlands as a model

الابتكار التكنولوجي كدعامة لضمان الأمن الغذائي: هولندا نموذجا

Boukellal Mohammed

University of Mostaganem (Algeria), mohammed.boukellal@univ-mosta.dz

Received: 06/03/2026

Accepted: 23/06/2026

Published:01/07/2026

Abstract:

This study aims to highlight the role of technological innovation as a catalyst for food security through the example of the Netherlands.

The study found that the adoption of advanced technologies, such as precision farming, smart greenhouses, and improved logistics, has led to a significant increase in the productivity and added value of the agricultural and farming sector.

This dynamic is reflected in the high level of exports and the Netherlands' leading position in global agricultural trade. The study also found that technological innovation simultaneously enhances economic competitiveness, productive performance, and contributes to ensuring the country's food security.

Keywords: Innovation; Technology ;Food security; Agriculture and farming sector; Modern techniques.

JELClassificationCodes: O33, Q16, Q18

ملخص:

تهدف هذه الدراسة إلى إبراز دور الابتكار التكنولوجي كعامل محفز للأمن الغذائي من خلال نموذج هولندا.

توصلت نتائج الدراسة أن اعتماد تقنيات متطورة، مثل الزراعة الدقيقة والبيوت الزجاجية الذكية وتحسين الخدمات اللوجستية، أدى إلى زيادة كبيرة في إنتاجية القطاع الزراعي والفلاحي وقيمته المضافة.

¹ *Corresponding author:* Boukellal Mohammed, *e-mail:* mohammed.boukellal@univ-mosta.dz

وتنعكس هذه الديناميكية في ارتفاع مستوى الصادرات ومكانة هولندا الرائدة في التجارة الزراعية العالمية. وتوصلت الدراسة أيضا إلى أن الابتكار التكنولوجي يعزز في الوقت نفسه القدرة التنافسية الاقتصادية والأداء الإنتاجي والمساهمة في ضمان الأمن الغذائي للبلد.

كلمات مفتاحية: الابتكار، التكنولوجيا، الأمن الغذائي، القطاع الزراعي والفلاحي، التقنيات الحديثة.

تصنيفات JEL: Q18، Q16، O33

1. INTRODUCTION

Food security is one of the major challenges of our time. Global agricultural systems are under increasing pressure due to population growth, climate change, depletion of natural resources, and geopolitical tensions. Innovation is therefore a strategic tool for improving the resilience, productivity, and sustainability of food systems. Innovation in agriculture, whether technological, organizational, or institutional, is radically changing production, processing, and distribution methods. This helps improve food availability while maximizing resource efficiency.

In addition to its impact on production, agricultural innovation has significant macroeconomic repercussions. Increased value added in the agricultural sector supports GDP growth, boosts exports, and strengthens the trade balance. It also stimulates the creation of highly skilled jobs, attracts investment, and enhances global competitiveness. Furthermore, by ensuring a constant and sustainable food supply, it contributes to socio-economic stability and balance.

To illustrate the role of innovation in ensuring food security, we have chosen to examine the Dutch model, renowned for its agricultural performance and high technology. Despite significant land restrictions, the Netherlands ranks among the world's largest agricultural exporters, thanks in particular to its strategic position in horticulture, dairy production, and meat. The Dutch case therefore proves to be a particularly relevant case study for understanding how innovation can simultaneously stimulate agricultural production, improve economic competitiveness, and ensure food security.

Study Problem:

The central question of this research can be formulated as follows: **to what extent does technological innovation contribute to the sustainable consolidation of food security in the Dutch agricultural model?**

Of this main question come to be grafted some secondary questions which are not less important:

1. How does agricultural innovation influence the productivity and efficiency of different agricultural sectors in the Netherlands?
2. What is the impact of agricultural technologies on national food security and supply stability?
3. To what extent does innovation contributes to strengthening overall agricultural production and improving the economic performance related to the sector?

Study Hypotheses:

Main hypothesis: The integration of technological innovation in Dutch agriculture significantly improves agricultural production and strengthens national food security.

This main hypothesis branches into the following sub-hypotheses:

1. Agricultural innovation increases the productivity and efficiency of different agricultural sectors in the Netherlands.
2. Agricultural technologies contribute to stabilizing the food supply and enhancing the country's food security.
3. Technological innovation makes it possible to increase overall agricultural production and improve the economic performance of the sector, particularly in terms of added value and competitiveness.

Study Objectives: This research mainly aims at the following objectives:

1. Study the impact of technological innovation on improving agricultural production, highlighting its influence on the productivity and efficiency of various agricultural fields.
2. Assess the impact of innovation in the agricultural sector on enhancing national food security, including availability, stability and sustainability of supply.
3. Study the effect of innovation on the economic performance of the agricultural sector, by scrutinizing value creation, competitiveness and export movement.
4. Scrutinize the impact of agricultural innovation on major macroeconomic indicators, such as GDP and trade balance.
5. Study the place of the Netherlands in the world agricultural trade, and assess the degree to which this position is associated with the technicality of the field.

2. Food safety and its dimensions:

2.1 Definition of food safety:

Food security can be initially defined as the capacity to ensure a

continuous supply of essential food commodities to the global population, with the aim of promoting increased food consumption while regulating price fluctuations (World Food Summit, 1974). This definition emphasizes two fundamental dimensions: guaranteeing food availability and maintaining price stability.

The most widely accepted and frequently cited definition of food security originates from the 1996 World Food Summit and was updated in 2021. According to this definition, food security exists when all people, at all times, have physical (social) and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

This definition highlights the multidimensional and cross-sectoral nature of food security, which was initially conceptualized through four key dimensions: food availability, food access, food utilization, and stability.

The Food and Agriculture Organization of the United Nations (FAO) has also provided another definition of food security, defining it as the provision of sufficient quantities of appropriate-quality food to communities in order to meet their needs in a sustainable manner. (Buqtaf & Harz Allah, 2022, pp. 224-251)

According to experts, food security is characterized by the following conditions: (Guettaf, 2024, pp. 459-470)

- **Adequacy:** the capacity to produce and maintain sufficient food supplies to meet the needs and preferences of the population;
- **Autonomy:** protecting countries from fluctuations in international markets that may affect food availability;
- **Stability:** managing seasonal and cyclical variations in food
- **Sustainability:** ensuring long-term continuity of food provision;
- **Equity:** guaranteeing that all segments of the population have access to adequate food.

Food security is also defined as the capacity of a society to provide its members with sufficient food in both the short and long term, in terms of quantity and quality, at prices that are compatible with their income levels (Hamdan, 1999, p. 34). Moreover, Harraq Misbah indicates that food security in a country is ensured when the following criteria are simultaneously satisfied: food availability, accessibility, proper utilization, continuity of supply, and the absence of risks to consumer health (Harrag Masbeh, 2019, pp. 162-188).

The term “food security” also refers to the right of peoples, states, or

unions to establish their own policies in the fields of agriculture and food. According to the Political Declaration of Non-Governmental and Civil Society Organizations at the Forum on Food Sovereignty, held in Rome in June 2002, the goal of achieving food sovereignty in the medium and long term is primarily based on the principle that all people worldwide have the right to healthy, culturally and nutritionally appropriate food. They should also have access to the resources necessary to produce their own food and the capacity to ensure their own survival and that of their communities (Leclercq & Ouimet, 2020).

The Arab Organization for Agricultural Development (AOAD) defines food security as the production of more food than a country's domestic needs in a balanced and economically efficient manner, where local food production possesses a competitive advantage that enables it to compete with foreign production in international markets (Menad & Zerouat Fatima, 2025, pp. 215-232).

In contrast, food insecurity is defined as the limited, insufficient, or unstable access of individuals and households to safe, nutritious, and socially acceptable food, both in terms of quantity and quality. This situation makes it difficult to meet essential dietary needs and to lead a healthy and productive life (Tarasuk, Mitchell, & Dachner, 2014, p. 03). Today, food insecurity is considered a major public health and social issue, as it can have significant consequences for individual well-being and health (Tarasuk, Mitchell, & Dachner, 2014, p. 02).

Based on all these definitions, it can be concluded that an individual is considered food secure when they have sufficient food resources to lead an active and healthy life. The same principle applies to all populations, whether urban or rural, wealthy or poor, young or old, male or female. A household is deemed food secure when its livelihood and environment are stable, including adequate food stocks and sufficient financial resources to meet basic needs. Food security is also linked to both agricultural and non-agricultural activities, as they provide diverse sources of food and/or income.

2.2 Dimensions of Food Security:

Food security is considered a major global issue and depends on multiple interrelated factors. It encompasses not only the availability of food but also its accessibility, quality, and proper utilization, while taking into account the regularity of supply over time. Understanding these factors is essential to identify measures and innovations that can enhance food security in the current context, characterized by population growth, climate

change, and economic crises.

a. Physical Availability of Food: Food security refers to the total quantity of food available in a country or region (at the macro level) or for a population or household (at the micro level). It involves assessing both the food currently available and the quantities expected to be available in the future. This requires that these resources actually exist in sufficient quantity and quality to meet the needs of individuals. It also indicates the minimum level of supply necessary to satisfy national dietary requirements, with a significant proportion of food products coming from domestic production rather than foreign imports.

b. Economic and Physical Access to Food: The term “access” refers to a household’s ability to obtain sufficient food to meet the dietary needs of each of its members. It involves assessing the population’s capacity to obtain available food over a specific period. This means that every individual should have the opportunity to access food in adequate quantity and quality, without material or economic barriers, at all times. Economic and logistical access to food implies that individuals must have the financial resources and the means to obtain sufficient and nutritious food (FAO, 2008, p. 01).

c. Food Utilization: Food utilization relates to the use of food at the micro level (household or individual), including the distribution of food within the household, its preparation, and individual consumption. It is an assessment of the population’s ability to access adequate food over a given period (FAO, 2008, p. 01). Determinant factors include physiological aspects (adequate nutrient absorption), health conditions (water quality and overall sanitation), and educational factors (food storage and handling practices, basic nutrition knowledge, etc.). Proper utilization of food resources is equally essential, as it significantly affects both the quality and quantity of available resources. In practice, utilization encompasses all processes involved in the preparation, processing, and storage of food resources.

d. Stability of the Three Dimensions and Cross-Cutting Elements: The concept of stability is linked to the principles of resource availability, access, and utilization. For a society to achieve food security, it must have continuous access to the necessary resources. This means that these resources should be available at all times, both temporally and geographically, even under difficult conditions such as market fluctuations, rising costs, or famines.

Cross-cutting elements encompass all aspects addressed by the

guidelines on the right to food that are not specifically covered by the four dimensions of food security. Nevertheless, these elements remain critical for achieving food security. This category includes issues such as education, participation, accountability, non-discrimination, transparency, human dignity, skills development, the rule of law, women's rights, gender equality, and the monitoring of food security (Prosperi, 2012, p. 44).

2.3 The Necessity of Food Security:

Food security is essential for the prosperity of societies and the stability of nations, as it ensures the availability of food in sufficient quantities, at affordable prices, and of adequate quality to allow people to live, work, and thrive. The absence of food security leads to higher rates of poverty and malnutrition, while reducing governments' capacity to manage crises, resulting in social and economic imbalances.

Ensuring food security is also crucial for maintaining the autonomy and sovereignty of nations. Countries that rely heavily on imports are vulnerable to external shocks, such as global price increases or geopolitical crises. Moreover, food security is closely linked to public health, education, and economic development. Indeed, individuals cannot study, work, or innovate without sufficient and nutritious food. These considerations underscore the critical importance of guaranteeing food security. (FAO, 2023).

a. Population Growth: According to the latest United Nations population projections, the world's population is expected to continue growing significantly over the coming decades. It is projected to reach approximately 8.5 billion people by 2030, driven by increases in life expectancy and population growth across various regions. Over the long term, forecasts indicate that the global population could approach 9.7 billion by 2050, despite a gradual decline in growth rates in some high-income regions with low fertility levels. These projections highlight the scale of future challenges related to food security, sustainable resource management, and the formulation of appropriate policies.

b. Conflicts and Insecurity: According to the 2023 edition of the Global Report on Food Crises, conflict and insecurity were the primary drivers of acute food insecurity in 2021, affecting 139.1 million people across 24 countries and territories. Economic shocks and extreme weather events were also identified as critical factors contributing to acute food insecurity, impacting 30.2 million people in 21 countries and 23.5 million people in eight countries, respectively. For several years, there has been a concerning trend of increasing exposure of populations to acute food insecurity due to

economic shocks (FAO, 2023).

c. Climate Change and Weather Events: Increasing climate variability not only affects agricultural production levels but also heightens the risks of extreme weather events, changes in crop patterns, and the emergence of pests and diseases. Ultimately, climate change places additional pressure on scarce natural resources, leading to local conflicts that undermine food security and nutrition, and may eventually drive migration when agriculture can no longer sustain livelihoods. Agriculture faces rising levels of risk due to uncertainties associated with climate change and the complex interactions between climate and land. Assessments of the planet's natural resources highlight their overexploitation, improper use, degradation, and vulnerability to pollution.

3. Technological innovation and its characteristics:

3.1 Definition of technological innovation:

The Longman dictionary defines it as any new invention or improved method of producing a good, or any change in production methods that gives the product an advantage over its competitors by allowing it to obtain a temporary monopoly (Adam, 1982, p. 264). As for Peter Drucker, he defined innovation as the organized abandonment of the old, thus confirming Schumpeter's statements that innovation is a creative destruction (Aboud, 2003, p. 66). According to Amabile, innovation and creativity are closely linked: "Every innovation stems from creative ideas, and it is through individuals and teams that this creativity is expressed, thus constituting the catalyst for innovation" (Amabile, 1996, p. 41). There is therefore an intrinsic link between creativity and innovation, because innovative creations can only emerge from the minds of creative individuals and teams.

Innovation is the dynamic transformation of creativity into a tangible product that conquers markets; creativity is the introduction of a new element in a new place to fulfill a new function in order to achieve better results; and renewal is the replacement of an old element by a new element in the same place to fulfill the same function. Only one out of ten original ideas produced by American companies becomes an invention, and this innovation often conquers the market (Amabile, 1996, p. 42).

The Organization for Economic Co-operation and Development defines innovation as all scientific, technical, commercial and financial measures necessary for the successful development and marketing of new or improved industrial products, the commercial use of new or improved

methods, processes or equipment, or the introduction of a new method in social service (Tarchi & Barberi, 2008, p. 01).

3.2 Types of technological innovation:

Innovation does not only consist in the development of new products; it can manifest itself in different ways depending on the needs and the context in which it occurs. Indeed, companies and institutions are trying to innovate in various ways to strengthen their competitiveness and meet market requirements.

a. Incremental innovation: Incremental or progressive innovation focuses primarily on product improvement. This improvement could refer to the technology used to develop the product. It can also concern certain aspects of products such as shape, color or aesthetics (Veryzer Jr, 1998, pp. 304-321). Geroski and Markides (2005) highlight that incremental innovation relies on existing skills and resources, and its influence on consumer behaviors is considered modest (Ravichandra & Lertwongsatien, 2005, pp. 237-276). According to Arnaud (2009), incremental innovation refers to an improvement in the performance of the product or service. It is often the result of a continuous improvement approach, such as that which quality can bring within a company.

b. Architectural innovation: According to (Clark, 1985) The overall structure of the product determines how the various elements will interact with each other. Here, a component is defined as a physically distinct part of the product that reflects an essential design concept and performs a clearly defined function (Abernathy & Clark, 1985, pp. 3-22). Architectural evolution is frequently stimulated by a change in an element, whether its dimension or another secondary criterion of its configuration, which generates new interactions and new relationships with other elements of the existing product. The essential thing is that the fundamental idea behind each element, as well as the related scientific and technical knowledge, remains unchanged.

c. Disruptive innovation: It is inevitable to mention Clayton Christensen, in the literature considered as the initiator of the concept of disruptive innovation. Christensen characterized this as an approach where a product or service is initially developed for the market and then rapidly rises in that same market, supplanting established competitors (Hardman, Steinberger-wilckens, & Horst, 2013, pp. 15438–15451). In this case, innovation and technology can be seen as a revolution making processes, services or products obsolete. Disruptive innovation is defined as the marketing of a

product or service that disrupts the operations of existing services in a field or structure. Disruptive innovation can occur at various levels, such as the industrial segment, industry structure and societal system.

d. Radical innovation: The Smartphone, as an illustration of a radical innovation, combines the characteristics of traditional mobile phones, cameras and video devices, location systems, partly computers and various other devices. Radical innovations, whose definition is unclear, are distinguished from incremental innovations by the degree of added value they provide to customers, (Dewar & Dutton, 1986, pp. 1422–1433). Their requirement for new knowledge and the necessary strategies and structures (Garcia & Calantone, 2002, pp. 110–132). Companies engage in radical innovation to take advantage of the opportunity to transform or design new markets, operate as (temporary) monopolies and dramatically boost profits. Particularly given the growing trend towards digitalization, it is highly likely that radical innovations will continue to gain momentum (Rubera & Kirca, 2012, pp. 130–147).

4. Innovations in the field of agriculture:

Innovation in the sectors of agriculture or rural enterprise has been a reality for thousands of years, whether through chance or informal initiative, but it especially attracts rural populations in search of innovative and more appropriate production methods and organization.

4.1 Definition of agricultural innovation:

According to the FAO, agricultural innovation is defined as: “The process by which individuals or organizations implement new or existing products, processes or modes of organization for the first time in a specific context in order to improve efficiency, competitiveness, resilience or environmental sustainability, thereby contributing to food security and nutrition, economic development, and sustainable management of natural resources” (FAO, 2018). Another definition that of the organization for economic co-operation and development (OECD, 2005) which defines innovation as being 'the implementation of a new product (good or service) or a product that has undergone substantial improvements, or a new process, a new marketing technique or a new method of organization applied to commercial practices, to the organization of work and external relations. According to Messak (2011), Technical innovation in agriculture can be defined as a "new combination of production factors, i.e. new productive options and new forms of consumption" (Messak, 2011, p. 57). In Schumpeter's terms, "when economics does something else, apart

from common practice, we can then speak of creative response." This definition mainly highlights an economic approach to innovation and leads to considering in particular its impact on income, work and natural resources (Poole, 2006, p. 26).

4.2 The concept of agricultural innovation systems:

Agricultural Innovation Systems (AIS) are the crucial element to optimize the economic, ecological and social outcomes of the agri-food industry. Agricultural research and development (R&D) has been shown to have long-lasting positive effects on increasing productivity, and technologies and methods can help optimize the sustainable use of natural resources. AIS, considered as a potential response to the challenges of the agri-food sector, are receiving renewed attention from decision makers (OCDE, 2013, p. 03). Thus, the idea of an innovation system provides a framework for study to understand and describe how infrastructures, institutions, organizations, networks and stakeholder strategies can promote the development of innovations in various dimensions: national, local or sectoral (Adam, 2023, p. 03).

The innovation system extends beyond the farmer and the researcher, encompassing the private sector, agencies responsible for technology diffusion as well as various other areas, to the broader policy and institutional level. The AIS encompass participatory approaches in rural areas, collaborations between the public and private sectors, as well as local innovations, among others. Agricultural innovation systems do not only represent a new form of innovation, they also embody "the diversity of innovation".

4.3 The fields of agricultural innovation:

In the agricultural sector, the main objective of innovation is to increase production (food products, animal feed, by-products) and improve quality (products, growing conditions, production processes). They generally deal with one of the following five areas: (Evenson, 1974, pp. 51-73)

a. cultivation: biological and genetic transformations, such as the introduction of new breeds or varieties with particular advantages, such as increased productivity or improved resistance to certain climatic and soil conditions; the integration of new species that extends the calendar of crops or diversifies the type of agriculture practiced; the use of new techniques such as grafting; the conversion of plant products into commercial crops.

b. Animals: biological or genetic modifications comparable to those mentioned above; new techniques for breeding current animals to increase

their yield - for example, the use of animals for their derived products such as wool, milk, blood and traction, rather than for their meat and skin exclusively; and others.

c. Cultivation conditions: incorporation of manure or other fertilizers; deepening the soil; drainage or watering; intensification of tillage; terracing to prevent erosion or obtain additional surface for cultivation; windbreaks; provision of supplementary feed or improvement of grazing for livestock.

d. Agricultural equipment: more efficient plows or adapted to different types of soil; harvesting machines; crushing equipment; water pumping systems...

e. Management methods: changes in the production system; land ownership and inheritance rights; size of cultivated land; accessibility of the labor force; transition to surplus production.

5. The importance of innovation in ensuring food safety:

With the increase in population and structural transformations in food production, trade and consumption, ensuring food security is a key challenge. Food security encompasses availability, quality, continuity and access to food, as well as the ability of communities to manage their nutrition. Multiple innovations to enhance food security are implemented at different scales. So just like in various other areas, innovation is the main driver of productivity improvement in agriculture. At the national level, innovation encourages the creation of higher added value and improved competitiveness and economic growth. It also participates in economic diversification, especially in the context of emerging economies. In the context of farms, the introduction of innovations should promote a more efficient distribution of resources, an increase in productivity and consequently an improvement in incomes. Innovation can also support improved environmental performance on farms. (OCDE, 2013, p. 17)

Innovation in agriculture has proven its ability to improve productivity and product quality. To maintain the sector's competitiveness, it must be continuous and adapted to changes in markets, resources and natural conditions. It allows us to produce more varied and nutritious foods, to provide raw materials for other uses without depleting natural resources, and to adjust agriculture to the impacts of climate change. (OCDE, 2013, p. 18)

5. The contribution of innovation to the Dutch economy and food security:

The Dutch example provides a particularly significant illustration of the strategic role of innovation in economic and agricultural change. In the Netherlands, the constant incorporation of advanced technologies into agriculture has not only promoted an increase in productivity and value added in the sector, but also consolidated the country's food security and its positioning on the global market. The review of this contribution highlights the relationships between innovation, economic efficiency and sustainability of the food system.

5.1 Netherlands and macroeconomic indicators:

The Netherlands is one of the four constituent countries of the Kingdom of the Netherlands, alongside Aruba, Curaçao, and Sint Maarten, which are located in the Caribbean. The country consists of 12 provinces in Western Europe and three Caribbean islands: Bonaire, Sint Eustatius, and Saba. The European part borders Belgium to the south and Germany to the east, while the North Sea lies to the north and west. The term "Holland" is often used to refer to the Netherlands, although it strictly applies only to the provinces of North Holland and South Holland.

The country covers an area of 41,540 km², of which about 33,893 km² island, and nearly 20% lies below sea level. Effective water management and flood protection measures are therefore essential. With a population of approximately 18 million, the Netherlands ranks among the most densely populated countries in the European Union, with about 496 inhabitants per square kilometer, making it the second most densely populated EU country after Malta.

Table 1. Macroeconomic indicators OF the Netherlands 2024

Indicator	Value /Estimate
GDP	Growth Around 0.9% to 1.1%
Gross domestic product (GDP)	1,227 billion USD
GDP per capita	68 393 USD
Inflation	3,2 %
Unemployment rate	3,7 %
Total population	17,9 million
Current account balance (% of GDP)	9,9 %
Public debt (% of GDP)	43,2 %

Source: Department for Business and Trade. (2026, February 2). *Netherlands – UK Trade and Investment Factsheet* (Official Statistics). Gov.uk. Available on :

<https://assets.publishing.service.gov.uk/media/697a1edec23c8fa26650debe/netherlands-trade-and-investment-factsheet-2026-02-02.pdf>

Dutch macroeconomic indicators for 2024 reflect a stable and dynamic economy. The country, with a gross domestic product of 1,227

billion dollars and a GDP per person amounting to 68,393 dollars, shows considerable wealth and significant productivity. The economic expansion, estimated at between 0.9% and 1.1%, remains modest, reflecting the challenges associated with global uncertainties and tensions in international markets.

The inflation rate of 3.2% signals a relative control of prices following recent changes, while the unemployment rate restricted to 3.7% reflects a robust labor market and high hiring capacity. With 17.9 million inhabitants, the total population is both a catalyst for consumption and a concern in terms of resource and infrastructure management.

From an external perspective, the current account surplus of 9.9% of GDP is a testament to the competitiveness of the Dutch economy and its dynamic involvement in world trade. Ultimately, a public debt maintained at 43.2% of GDP demonstrates sound budgetary management that ensures the financial stability and economic strength of the nation. Overall, this information indicates that the economy of the Netherlands is strong and able to promote growth, withstand external shocks and maintain a high standard of living for its citizens.

5.2 Types of innovation in Dutch agriculture:

Agriculture in the Netherlands is characterized by a high degree of innovation, which can be seen in production technologies, organizational systems and sustainable methods. These advances contribute to increasing productivity, farm competitiveness and the sustainability of food systems (Ocde, 2015).

a. Production technological innovations:

- **Precision agriculture:** This approach allows optimizing resource management at the intra-plot scale through the use of sensors, drones, and data analysis. Irrigation, fertilization and crop protection are precisely adjusted, reducing costs, protecting the environment and increasing efficiency (Paul van Zoggel, 2025).

- **Automation and robotics:** Farms in the Netherlands implement automated systems for planting, crop tracking, and sometimes even harvesting. Artificial intelligence examines agronomic information in order to give live advice, thus decreasing the need for manpower and post-harvest losses. (Wageningen, 2025).

- **Greenhouse crops:** High-tech greenhouses combine climate management, LED lighting and automation of watering and plant nutrition.

This model guarantees stable production and high yields throughout the year, regardless of external conditions.

b. Organizational innovation and innovation systems:

-Integrated Innovation Systems (AKIS): The Dutch model is based on collaboration between researchers, farmers, businesses and public authorities, thus promoting accelerated adoption of technologies and the spread of innovative methods (OCDe, 2023).

-Partnerships and cooperation: Mutual assistance between private actors, universities and public authorities, usually through consortia and national programmes, allows for the optimization of resources, to accelerate applied research and simplify access to advanced technologies.

c. Innovations in sustainability:

-Circular agriculture: Circular practices, such as water reuse, nutrient recovery and biogas production, reduce the use of synthetic inputs and increase environmental efficiency (Meijer, 2011).

-Resource efficiency: The targeted use of digital inputs reduces water, fertilizer and pesticide consumption, thus improving the sustainability and resilience of food systems in the face of environmental and climate constraints.

5.3 Agricultural production in the Netherlands:

Despite its small size, the Netherlands is one of the largest agricultural producers in the world. Thanks to technological advances, a powerful organization and a strong presence in global markets, their agricultural production is remarkably varied, including greenhouse crops, dairy products, not to mention flowers and cereals.

a. Agricultural crop production:

The table below illustrates the main data related to crop agricultural production in the Netherlands in 2024.

Table 2. Agricultural crop production 2024

Plant production	Volume / Value	Economic characteristic
Wheat Limited	1.1 million tons	production, domestic use
arley & Maize	0.8 million tons	Animal feed
Potatoes	7 million tons	European leader, strong export
Vegetables (tomatoes, peppers, cucumbers)	5 million tons	Production under high-tech greenhouses
Flowers and ornamental plants	11.9 to 13 billion dollars	first world (40% of global trade)
Apples	300,000 tons	European export
Pears	400,000 tons	European export

Fodder crops (maize, grass)	Several million tons	Support for the dairy sector
-----------------------------	----------------------	------------------------------

Source: Developed by the author based on available data on:

1. Centraal Bureau voor de Statistiek | CBS : <https://www.cbs.nl/en-gb/news/2025/03/value-of-agricultural-exports-up-by-nearly-5-percent-in-2024>
2. Centraal Bureau voor de Statistiek | CBS : <https://www.cbs.nl/en-gb/publication/2025/03/the-dutch-agriculture-sector-in-2025-an-international-perspective>

The table depicts the Dutch agricultural production for the year 2024, highlighting the diversity and specialization inherent in this sector. Potatoes present a quantity of 7 million tons, while vegetables such as tomatoes, peppers and cucumbers total 5 million tons, mainly grown in high-tech greenhouses to ensure high yields and excellent quality. The production of flowers and decorative plants, estimated between 11.9 and 13 billion dollars, is the most valuable, positioning the Netherlands at the top of the world ranking with a share of 40% in international trade.

Cereals, which include 1.1 million tons of wheat, barley and maize with 0.8 million tons, are mainly intended for domestic consumption and animal feed. European exports are greatly influenced by fruits such as apples, with 300,000 tons, and pears, reaching 400,000 tons. Crops such as corn and grass contribute to the dairy sector by providing essential elements. These statistics reveal an intensive, innovative and export-oriented agricultural system, combining productivity, sustainability and competitiveness on the international stage.

b. Animal production:

Livestock farming remains an essential pillar of the Dutch agricultural model, particularly for dairy products, despite growing environmental constraints.

The table below illustrates the main data related to Animal production in the Netherlands in 2024.

Table 3. Animal production 2024

Type of farming	Number
Cattle	3.78 million head
Pigs	10.5 million
Poultry	89 million

Source: Developed by the author based on available data on:

1. Centraal Bureau voor de Statistiek | CBS : <https://www.cbs.nl/en-gb/news/2025/03/value-of-agricultural-exports-up-by-nearly-5-percent-in-2024>
2. Centraal Bureau voor de Statistiek | CBS : <https://www.cbs.nl/en-gb/publication/2025/03/the-dutch-agriculture-sector-in-2025-an-international-perspective>

The table highlights the crucial data concerning livestock in the Netherlands for the year 2024, highlighting the predominant role of livestock in the composition of national agriculture. The cattle population amounts to approximately 3.78 million animals, which demonstrates the crucial importance of the dairy sector in the agricultural economy of the Netherlands. Indeed, the Netherlands ranks among the leading producers of milk and dairy products in Europe, a large part of this production being destined for processing and export.

Pig farming is also an area of prime importance, housing about 10.5 million pigs, which places the country among the major producers of pig meat in Europe. Not only does this production feed the domestic market, but it is also intended for export to various European countries.

The poultry sector is characterized by a population of approximately 89 million birds, contributing to the production of meat and eggs for domestic consumption and exports.

Overall, these data illustrate an intensive and efficient livestock farming system, supporting the competitiveness of Dutch agriculture and its role in consolidating food security.

c. Milk production:

The table below illustrates the main data related to Milk production in the Netherlands in 2024:

Table 4. Milk production 2024

Indicator	Value / quantity
total milk production	13.8 – 14 billion kg/year
Number of dairy cows	1.6 million
Main products	Fromage, beurre, lait en poudre

Source: Developed by the author based on available data on:

1. Centraal Bureau voor de Statistiek | CBS <https://www.cbs.nl/en-gb/news/2024/48/dairy-cow-population-down-slightly-in-2024?utm>
2. ZuivelNL – Dutch Dairy in Figures 2024: <https://zuivel-nl.files.svdcdn.com/production/images/ZuivelNL-Dutch-Dairy-in-Figures-2024-spread-web.pdf?dm=1753774750>

The table specifies the crucial role of the dairy industry in agriculture in the Netherlands. In 2024, overall milk production amounts to approximately 13.8 to 14 billion kg, thanks to a workforce of about 1.6 million dairy cows. This production is mainly converted into cheese, butter and milk powder, products that play a predominant role in the agri-food sector and Dutch exports.

d. Agricultural exports of the Netherlands for 2024:

The following text mentions the exporting of the Netherlands in dollars:

Table 5. Agricultural exports of the Netherlands for 2024

Sector / Product	Value (billion Dollars)
Total milk production	13,28
Horticulture (fleurs, plantes)	12,85
Meat (pork, poultry, beef)	11,56
Vegetables & potatoes	9,61
Cocoa & derived products	10,69
Total agricultural exports	139,21

Source: Developed by the author based on available data on:

1. Statistics Netherlands (CBS) – Agricultural exports 2024 <https://www.cbs.nl/en-gb/news/2025/03/value-of-agricultural-exports-up-by-nearly-5-percent-in-2024?utm>
2. CBS & Wageningen Economic Research – Dutch agricultural sector report: [file:///C:/Users/HOUSE/Downloads/De%20Nederlandse%20agrarische%20sector%20internationaal%202025%20\(2\).pdf](file:///C:/Users/HOUSE/Downloads/De%20Nederlandse%20agrarische%20sector%20internationaal%202025%20(2).pdf)

The table reveals the importance of agricultural exports for the economy of the Netherlands. The total sum of agricultural exports in 2024 amounts to approximately \$139.21 billion, highlighting the position of the Netherlands as one of the leading exporters globally. The dairy sector leads with a turnover of 13.28 billion dollars, followed by horticulture which generates 12.85 billion and meat which represents 11.56 billion. Major export categories include cocoa products \$10.69 billion and vegetables and potatoes \$9.61 billion. These results testify to a highly specialized agriculture and strongly oriented towards global markets.

6. CONCLUSION

To conclude, this research demonstrates that innovation in the agricultural field is a crucial strategic element to ensure food security, especially in a global context characterized by an increasing demography, climate changes, an instability of markets and economic constraints. Technological advances, whether in precision farming, automation, sophisticated greenhouses or sustainable methods, promote increased productivity, improved production quality and optimized use of natural

resources. This contributes to strengthening the resilience and competitiveness of food systems.

In the Netherlands, the steady implementation of advanced technologies and the efficient structuring of agricultural chains have ensured a solid and constant food security. Not only did the production of milk, horticulture and market gardening as well as intensive livestock farming guarantee domestic supply, but they also encouraged unprecedented agricultural exports, thus strengthening the country's position on the world market. This dynamic would corroborate our research assumptions that innovation in the agricultural sector promotes improved production, ensures food security and supports economic competitiveness.

Innovation influences all four aspects of food safety. In terms of availability, it increases the volumes and consistency of productions. It promotes more efficient distribution and improved economic accessibility for access. With regard to use, it ensures the nutritional quality and safety of foodstuffs. Finally, in terms of stability, this decreases sensitivity to climate and economic variations, thus strengthening the resilience of the food system.

As regards recommendations, it is crucial to increase and support investments in applied research and sustainable technologies, to consolidate collaboration between public and private stakeholders and research centers, as well as to promote a rapid spread of innovations within farms. Furthermore, the adoption of circular and ecological methods must remain a priority to ensure the sustainability and soundness of food security in the face of future challenges.

5. Bibliography List:

1. Abernathy, W. J., & Clark, K. B. (1985). Innovation: Mapping the winds of creative destruction. *Research policy* , 14 (1), 3-22.
2. Aboud, N. (2003). *Gestion de l'innovation, concepts, caractéristiques et expériences modernes* (éd. 1). Amman, Jordanie: Dar Wael pour l'édition et la distribution.
3. Adam, G. (1982). *Longman Dictionary of Business English*. Beirut: York Press.
4. Adam, S. (2023). Evaluation de la performance des systèmes d'innovation agricole dans les pays en développement : une analyse par les services supports appliquée aux innovations agroécologiques au Cameroun. *Thèse de Doctorat* . Université de Montpellier .
5. Amabile, T. (1996). *Creativity in context*. New York: Westview Press.
6. Buqtaf, M. H., & Harz Allah, K. (2022). Achieving food security through the continuity of the agricultural investment system in Algerian legislation. *Journal of Legal and Political Research and Studies* , 06 (01), 224-251.
7. Dewar, R., & Dutton, J. E. (1986). The adoption of radical and incremental innovations: An empirical analysis. *Management Science* , 32 (11), 1422–1433.
8. Evenson, R. (1974). International diffusion of agrarian technology. *The Journal of Economic History* , 34 (01), 51-73.
9. FAO. (2023). *Défis liés à la sécurité alimentaire mondiale et principales causes: conflits et guerres en Ukraine et dans d'autres pays, ralentissements et fléchissements, et changement climatique*. Rome.
10. FAO. (2018). *Symposium international sur l'innovation agricole au service des agriculteurs familiaux : libérer le potentiel de l'innovation agricole pour atteindre les objectifs de développement durable*. .
11. FAO, O. d. (2008). *Introduction aux concepts de la sécurité alimentaire . Guides pratiques. Programme CE-FAO « Sécurité alimentaire : l'information pour l'action »*. USA: FAO.
12. Garcia, R., & Calantone, R. (2002). A critical look at technological innovation typology and innovativeness terminology: A literature review. *Journal of Product Innovation Management* , 19 (2), 110–132.
13. Guettaf, S. (2024). Uses of artificial intelligence in achieving food security in Algeria. *Journal of Economic Integration* , 12 (03), 459-470.
14. Hamdan, M. R. (1999). *Food Security Theory System and Application*. Amman: Dar Wael Publishing.

15. Hardman, S., Steinberger-wilckens, R., & Horst, D. (2013). Disruptive innovations: The case for hydrogen fuel cells and battery electric vehicles. *International Journal of Hydrogen Energy* , 38 (35), 15438–15451.
16. Harrag Masbeh, B. y. (2019). la sécurité alimentaire en Algérie une étude analytique sur les céréales. *revue de l'économie financière et des affaires* , 03 (02), 162-188.
17. Leclercq, J.-B., & Ouimet, A.-M. (2020). L'organisation communautaire comme réponse collective aux enjeux de l'insécurité alimentaire au Québec. *Anthropology of food* (S15).
18. Meijer, B. J. (2011). *Systems innovations in agriculture in the Netherlands*. Consulté le 03 02, 2026, sur https://www.researchgate.net/publication/254843679_Systems_innovations_in_agriculture_in_the_Netherlands
19. Menad, L., & Zerouat Fatima, Z. (2025). The impact of the Russian-Ukrainian crisis on food security in Algeria through wheat imports: An econometric modeling attempt for wheat production (2005/2022). *Strategy & Development Review* , 15 (02).
20. Messak, M. R. (2011). Recherche sur les causes de l'adoption ou de la non-adoption des techniques d'irrigation économes en eau. *Thèse de doctorat* . ENSA Alger.
21. OCDE. (2013). *Les systèmes d'innovation agricole : Cadre pour l'analyse du rôle des pouvoirs publics*. OCDE.
22. Ocd. (2015). *Innovation, Agricultural Productivity and Sustainability in the Netherlands. OECD Food and Agricultural Reviews*. PARIS: OECD Publishing.
23. OCDe. (2023). *Policies for the Future of Farming and Food in the Netherlands*. (OCDE, Éd.) Consulté le 03 02, 2026, sur https://www.oecd.org/content/dam/oecd/en/publications/reports/2023/06/policies-for-the-future-of-farming-and-food-in-the-netherlands_c632ba3d/bb16dea4-en.pdf
24. Paul van Zoggel, M. (2025). *Precision agriculture*. Récupéré sur <https://www.wur.nl/en/research/plant/precision-agriculture>
25. Poole, N. (2006, Janvier). L'innovation: enjeux, contraintes et opportunités pour les ruraux pauvres. *Document de synthèse* .
26. Prosperi, P. (2012). *Sélection et formulation d'indicateurs spécifiques de la sécurité alimentaire durable (sustainable food security) en Méditerranée*. These de Doctorat: Institut Agronomique Méditerranéen de Montpellier.

27. Ravichandra, T., & Lertwongsatien, C. (2005). Effect of information systems resources and capabilities on firm performance: A resource-based perspective.,21(4), . *Journal of management information systems* , 237-276.
28. Rubera, G., & Kirca, A. (2012). Firm innovativeness and its performance outcomes: A meta-analytic review and theoretical integration. *Journal of Marketing* , 76 (3), 130–147.
29. Tarasuk, V., Mitchell, A., & Dachner, N. (2014). *L'insécurité alimentaire des ménages au Canada*. Toronto: Research to identify policy options to reduce food insecurity (PROOF).
30. Tarchi, M., & Barberi, M. a. (2008). Rôle et importance de l'innovation dans le renforcement de la compétitivité des entreprises économiques algériennes dans le contexte de l'économie du savoir. *intervention présentée lors du colloque scientifique international* (p. 01). Université Hassiba Bouali-Chlef.
31. Veryzer Jr, R. W. (1998). Discontinuous innovation and the new product development process. *Journal of Product Innovation Management: an international publication of the product development & management association* , 15, 304-321.
32. Wageningen, U. R. (2025). *AI, robotics and smart cultivation technologies*. Récupéré sur <https://www.wur.nl/en/research/plant/ai-robotics-and-smart-cultivation-technologies>