

RESEARCH

Open Access



Values and costs of emergency stocks of agricultural inputs for enhancing food security in Sweden

Ing-Marie Gren^{1*}, Hans Andersson¹, Lars Jonasson² and Rickard Knutsson³

Abstract

Emergency stocks are established to secure food supplies in the event of crisis and war. The net value of an emergency stock of an agricultural input depends on the cost of storing and the production value of the input in the case of a crisis event. In this study, such net values are calculated for five agricultural inputs (fuel, nitrogen fertilizer, seeds, pesticides and protein feed) for a crisis with a 50% reduction in the supply of inputs. The production value of each input is calculated using the price elasticity of demand for inputs and the cost of stocks is estimated through interviews with industry-specific experts. Results from the qualitative analyses show that farmers buying the inputs always gain from the use of emergency stocks, while the effect on sellers is determined by relative changes in prices and quantities with and without releasing the stock in the crisis event. The estimated cost of stockpiling as a percentage of the input price without a crisis varies between 5% (pesticides) and 14% (diesel fuel). The results of a 50% reduction in the available supply of each input reveal large variations in the farmers' and sellers' net value of emergency stocks in the event of a rapid liquidation: between 0.08 billion euros (pesticides) and 0.59 billion euros (diesel fuel). However, stock disposal can result in lower profits for sellers of the inputs. A comparison of different mechanisms show that any losses can be compensated and provide net revenues for the stock owner. Furthermore, the net value for each input decreases with the length of the period between the stock build-up and crisis. The cost of holding emergency stocks arises every year, while the economic value materializes in the year of a crisis. This is relevant for rebuilding civil defence in a broader sense. This highlights the importance of timing stockpiling for effective food preparedness.

Keywords Stockpiling, Agricultural inputs, Costs, Values, Sellers, Farmers, Sweden

*Correspondence:

Ing-Marie Gren
ing-marie.gren@slu.se

¹Department of Economics, Swedish University of Agricultural Sciences,
Box 7013, Uppsala 75007, Sweden

²Lantbruksekonomien, Haraldsmåla gård, Eringsboda 372 98, Sweden

³National Veterinary Institute, Ulls väg 2B, Uppsala 751 89, Sweden



© The Author(s) 2026. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

Introduction

Ongoing climate change and geopolitical tensions with an impact on trade and the digital logistics infrastructure are challenging global food security. Several countries have recognized the need to provide critical goods and inputs during crisis scenarios, such as the EU initiative for a new stockpiling strategy [1] and contingency plan for ensuring food security [2]. Against this background and the fact that Sweden joined NATO in 2024, the Government Offices of Sweden note that Sweden's resilience during various crises requires secured access to critical goods and services, such as essential production factors for producing food [3].

Sweden developed an extensive food security system after the Second World War, which included emergency stocks of various agricultural inputs and food items along with their geographical location [4]. During the Cold War, the storage capacity for agricultural inputs was greatly increased and subject to the responsibility of the Swedish Civil Contingency Agency [5]. The stocks were gradually phased out and completely emptied of inputs in 1997 and of food products a couple of years later. However, current geopolitical conditions have brought the issue of emergency stocks back to the forefront as the result of a governmental investigation of food security [3] and, more specifically, regarding the need to store input goods for the agricultural sector to ensure a certain level of food production [6].

Several studies have pointed to the severe economic effects, mainly on developing countries, of a crisis in terms of trade disruptions and fluctuating prices without the accessibility of food stocks [7, 8]. A study of Sweden revealed that costs can be extensive for farmers if imports of agricultural inputs are halved compared to a baseline scenario without a crisis [9]. Profits in the agricultural sector could be reduced by 55% due to a decrease in imports of fossil fuels and by 25% due to a decrease in imports of nitrogen fertilizers. Stocks of feed and food may reduce such costs, but also entail expenses for managing and investing in storage capacity. The net economic value depends on the costs of stockpiling and on the value of using the stocks in a crisis situation. The value, in turn, is determined by the contribution of the stocks to food security, the concept of which is four dimensional and includes, in general, physical, economic and stable access to food with sufficient nutrient content. There is a large body of literature on the measurement of food security in one or several of these aspects [10, 11].

The purpose of this study is to calculate the net economic value of emergency stocks for five essential agricultural inputs (fossil fuel, nitrogen fertilizer, seeds, pesticides and protein feed) in Sweden. The choice of these inputs rests on prioritizing emergency stocks of agricultural inputs by the Swedish Board of Agriculture

[6]. The sufficient supply of key agricultural inputs, such as fertilizer and fuel, in a time of crisis has also been emphasized by the European Commission [2]. A limitation is made by calculating the value of stock releases of the inputs for sellers and buyers, i.e. farmers. Estimating contributions to food security would require information on the use of the inputs for producing different types of food and their nutrient content. Data for this are not available. The net economic value of an emergency stock of each input is then calculated as the sum of the stock value for sellers and farmers net of stockpiling costs.

The stock release value for farmers is defined as the net production value of the input and the value for sellers as the net income from selling the input. The size of these values depends on several factors, such as the impact of the stock release on the price of the input, effects on the use of other inputs and on the demand for the foods produced by the inputs. This study uses a simplified analysis where the production value is calculated based on information about the demand for the inputs at different factor prices. This reflects the marginal production value of the input. Advantages with this approach are the need for a limited set of data and simple calculation methods. Costs for emergency stocks include capital costs for investments in suitable storage buildings, maintenance costs and interest on the capital tied up in the stock. Data on these items are obtained from industry-specific experts.

There is a relatively large body of literature that has analysed the effects of governance measures, such as trade regulation and storage reserves to increase food security in terms of physical and economic access to food, especially in developing countries, but without calculating the economic value (see meta-analysis in [11]). A few studies have analysed the value for producers and consumers of using stocks to stabilize the prices of essential foods [12–14] or of stock releases in times of crisis [15, 16]. A number of studies have estimated the costs of emergency stocks, but without calculating their economic value [6, 17–21].

The main contribution of this study is the calculation of the economic benefits as well as the costs of emergency stocks of agricultural inputs, which has not been done in any previous study. Another is the relatively simple method suggested for these calculations, which rests on a limited set of data. The study is organized as follows. A brief literature review of studies calculating either the costs or values of emergency stock is presented in Sect. 2, followed by the conceptual framework for our calculations and associated qualitative analyses in Sect. 3. Data for calculating stock values and costs are reported in Sect. 4 and the results are presented in Sect. 5. The study ends with a discussion and conclusions.

Literature overview

In the literature, the value of stockpiling food has been calculated as the impacts on producers and consumers, but in different ways depending on whether the purpose of stockpiling is to stabilize prices or to ensure food in times of crisis. A majority of the studies estimated the values of stabilizing prices in a theoretical framework [8, 12–14], with a few empirical applications [20]. The literature on the value of emergency stocks is much smaller and diverse with respect to methods used [15, 16]. Wesseler [15] presented a theoretical model of impacts on producers and consumers of a given food stock, but with an uncertain timing of the crisis. Gren et al. [16] applied another approach where the value of wild animal game as emergency stock was calculated as the cost for the agricultural sector to produce the same amount of nutrients.

However, almost all empirical studies on the economic effects of emergency stocks of agricultural inputs and foods estimate only the costs, which are calculated for

different crisis scenarios, countries, goods and in different ways (Table 1).

The calculated annual costs of emergency stocks range between 0.02 and 0.11 billion euros due to differences in, among others, the choice of crisis scenario, problem formulation and calculation methods. Two studies calculated the costs for the agricultural sector to achieve predetermined food security targets as measured in the minimum amount of nutrients under a given supply decrease scenario [17, 18]. Folkesson [18] minimized the total cost of production preparedness and stockpiling in a dynamic optimization model taking into account the relationship between grain and livestock production, risks in cultivation, restrictions on emergency food and requirements for crop rotation and land use in primary production. The range in estimated costs is due to the risk in crop yield affected by weather conditions, for example.

The other studies estimate the cost of stockpiling feed and/or food without specifying the commodities [19, 21] or for a single commodity (grain) [20, 22]. Apart from [22], none of the studies reports different storage cost components. The Swedish Board of Agriculture [22] calculated the cost per tonne of stored grain specified as the annualized capital cost of investment in silos.

Table 1 Studies on the costs and values of emergency stocks of agricultural inputs and foods in different regions, scenarios and goods

Country, year	Reference	Scenario	Stored goods	Cost ^a	Value ^a
Sweden, 1966	Gulbrandson and Lindbeck [17]	Trade blockade for 3 years	Agricultural inputs and food items	0.2 billion euros/year	
Sweden, 1973	Folkesson [18]	Trade blockade for 3 years	Agricultural inputs and food items	0.04–0.11 billion euros/year	
Ethiopia, 2012	World Bank [20]	3–9 months	Grain	35–54 USD/tonne	
Germany (DE) and Switzerland (CH), 2019	Stenérus et al. [19]	Decrease in supply for 3–4 months	Food items	0.02 (DE) and 0.4 (CH) billion euros/year	
Sweden, 2022	MSB [21]	3-month trade blockade	Agricultural inputs	0.06 billion euros/year	
Sweden, 2024	Gren et al. [16]	1-year trade blockade	Wild game animals		0.01–0.45 billion euros/year
Sweden, 2024	SBA [22]	Not specified	Grain	26 euros/tonne/year	

^a cost of storage, euros at 2023 price level

Conceptual framework

The point of departure in this study is a crisis where the supply of an input is reduced drastically from Business As Usual (BAU) to X^{cr} because of trade restrictions, for example. This decrease is counteracted by disposal of the stock X^s and the supply of the input is then $X^{csc} = X^{cr} + X^s$. The net economic value of the stock, $NEVS$, is calculated as the difference between values with and without the stock disposal minus the cost of stockpiling. This is defined as:

$$NEVS = V(X^{csc}) - V(X^{cr}) - C(X^s) \quad (1)$$

where $V(X^{csc})$ and $V(X^{cr})$ are the values with and without the stock disposal respectively and $C(X^s)$ is the cost of stockpiling. This includes the costs for facilities and the operating costs of the stock (see Sect. 4.2 for more details). The value in both cases is defined as the sum of profits from selling the input, the ‘producer surplus’ (PS), and farmers’ profits from purchasing the input, described as the farmer surplus (FS). The value is then defined as $V(X) = PS + FS$. Simple functions are assumed where $PS = pX - C(X)$ and p is the price of the input before the crisis and $C(X)$ is a cost function showing how the cost increases as production of the input increases. Similarly, the farmer surplus of the input is defined as $FS = I(X) - pX$ where $I(X)$ shows the production value of the input and pX is the cost.

The equilibrium prices with and without the stock disposal are p^{crs} and p^{cr} respectively, where $p^{crs} < p^{cr}$. In order to assess the effects on PS , it is assumed that the sellers obtain income from selling the stock of the input, but the stock is owned and paid for by the government. Such a system has been suggested by a Swedish governmental investigation [3]. This means that the sellers can sell the quantity X^{crs} to farmers at the equilibrium price p^{crs} when the stock is released. The effects on PS and FS of the disposal of X^s are then calculated as:

$$PS(X^s) = p^{crs} X^{crs} - p^{cr} X^{cr} \quad (2)$$

$$FS(X^s) = I(X^{crs}) - p^{crs} X^{crs} - (I(X^{cr}) - p^{cr} X^{cr}) \quad (3)$$

Given these definitions, $PS(X^s) > (<) 0$ depending on the relation between changes in equilibrium price and quantity of the input due to the disposal. The stock disposal raises the supply of the input, which, in turn, reduces the equilibrium price and the impact on PS is then determined as:

$$PS(X^s) > (<) 0 \text{ when } \frac{p^{crs}}{p^{cr}} > (<) \frac{X^{cr}}{X^{crs}} \quad (4)$$

The left-hand side of the inequality expression in Eq. (4) shows the relative decrease in price due to the stock disposal and the right-hand side is the relative increase in quantity. The sellers' surplus of the disposal of the stock is, thereby, positive when the relative decrease in price is lower than the relative increase in quantity. For example, if the stock disposal implies doubling the input supply in the crisis situation (i.e., when the right-hand side of Eq. (4) is 0.5), the price must decrease by less than 50% (i.e., the left-hand side is > 0.5). The losses from a decrease in price due to the stock disposal are then compensated by the increase in benefits from larger sales of the input. The amount of the price and quantity impacts of a given supply increase are determined by the farmers' options to adjust production. When input demand is elastic, i.e. when the percentage change in input demand is higher than the percentage change in price, the adjustment options are high and vice versa when demand is inelastic.

Unlike the seller surplus, the farmer surplus of the stock disposal is always positive:

$$FS(X^s) = I(X^{crs}) - p^{crs} X^{crs} - (I(X^{cr}) - p^{cr} X^{cr}) > 0 \quad (5)$$

Income increases from the disposal of X^s and the equilibrium input price decreases.

Calculating $PS(X^s)$ and $FS(X^s)$ as defined in Eqs. (2)-(3), the $NEVS$ are estimated as the differences in farmers'

income from the input with and without disposal of the stock minus the storage cost. This is written as:

$$NEVS = I(X^{crs}) - I(X^{cr}) - cX^s \quad (6)$$

However, an aspect not considered in Eq. (6) is that stockpiling costs are incurred during a period without a crisis, while the value is obtained when the stock is disposed of in a crisis situation. A long (short) period of time without a crisis entails relatively high (low) storage costs. In addition, the discount rate implies that future stockpiling costs and value are reduced. The value of the stock then decreases during the period before a crisis occurs. Regardless of the time period, the value is calculated based on the assumption that the supply of the input increases by emptying the stock during the year the crisis occurs. This means that the stock must be available at the beginning of the crisis year. The net economic value of the stock in period T then becomes:

$$NEVS^T = (I(X^{crs}) - I(X^{cr}))\rho^T - \sum_{t=0}^{T-1} cX^s \rho^t \quad (7)$$

where $\rho^t = 1/(1+r)^t$ is the discount factor with the discount rate r .

The government's budget net revenues (BNR) from a stock release can be negative or positive depending on the relationship between the unit cost of stockpiling, c , and the stock release price, p^{crs} , according to:

$$BNR = (p^{crs} - c)X^s \quad (8)$$

A relatively low X^s implies a high p^{crs} and vice versa. Depending on the policy design, positive BNR can be used to compensate any seller losses from the release of the stocks.

Although simple, the conceptual analysis enables the following qualitative conclusions to be made:

- FS is always positive from the disposal of input stock in a crisis situation.
- PS is positive (negative) for a relatively low (high) reduction in the equilibrium price compared with a high (low) increase in the stock release.

-The timing of a crisis and subsequent disposal of stocks affect the $NEVS$; a long period of

stockpiling before a crisis leads to relatively low $NEVS$ and vice versa.

- A stock owner's budget net revenues can be positive and used to compensate any seller losses from a stock release.

Description of data

There are no data on either production values or stockpiling cost at different input and stock levels for any of the five chosen inputs (nitrogen fertilizers, seeds, pesticides, protein feed and diesel fuel). Calculations have, therefore, been made by approximating production values with the use of estimated price elasticities of input demand in the literature. These are estimated using econometric methods based on actual input prices and demand by farmers during a time period with fluctuating prices and associated input demands. Such data are not available for stockpiling costs and estimates are based on expert judgements.

The production value of an agricultural input

The production value, i.e., income, of each input is calculated based on demand for an input at different given input prices. This approach has been used by several studies in environmental economics e.g., [23, 24]. An underlying assumption is that the farmer purchases an input as long as the marginal revenue (value of a marginal product) is larger than the marginal cost, i.e., the price, of the input. The marginal revenue is, in turn, determined by the prices of the food sold to its consumers and the marginal production of the food items by the input. A simplification is made in this study that the consumer prices are not affected, since the calculations of such changes would require a more complex partial equilibrium sector model. The farmers' demand is, consequently, a function of the input price, $X = X(p)$. However, in the present study, the supply of X is exogenous and the price is determined by farmers' responses to the change in X . An increase in X generates a decrease in the marginal revenue of the input and the farmers will buy more of the input only if the price (i.e., marginal cost) is decreased and vice versa. This response is found from the inverse of the demand function, $p = p(X)$, which shows the equilibrium input price at each level of X . The production value of the total use of the input is then obtained by integrating the inverse demand according to:

$$I(X) = \int_0^{X^n} p(X) dX \quad (9)$$

where X^n is the supply of inputs under the two different scenarios $n = X^{cr}, X^{crs}$ (crisis without and with the stock release). A linear function $p = p^{max} - aX$ is assumed, where p^{max} is the maximum price farmers are willing to pay for the input and the coefficient a shows the change in p from a unit change in X . Both p^{max} and a are calculated based on existing estimates of price elasticities of input demand and official statistics on the levels of price and quantity in 2023.

Estimates of price elasticities for Sweden are available for nitrogen fertilizers, herbicides, fungicides and insecticides. The estimated price elasticity of nitrogen fertilizers varies between -0.2 and -0.5 , i.e., a 1% increase in the price of commercial nitrogen fertilizer results in a decrease in demand of between 0.2% and 0.5% [25, 26]. This implies that the price of the input decreases between 2% and 5% if there is a 1% increase in the input supply. There are also a number of studies that calculate price elasticity for pesticides (meta-analysis in [27]). In this study, we use the elasticities estimated by [28] for the demand for herbicides, fungicides and insecticides in Sweden. These amount to -0.97 , -0.34 and -0.16 respectively. Such elasticity is not available for glyphosate and it is assumed to be the same as for herbicides. Several studies have estimated price elasticities of diesel demand for Sweden [29–31], but not specifically for agriculture. The results for total demand of diesel show a range between -0.2 and -0.6 and we assume an elasticity of -0.2 for the agricultural demand in the present study.

Unlike fertilizers, pesticides and fuel, there are quite a few price elasticity estimates for seeds and protein feed. We have only found studies on price elasticity estimates of feed in different regions of the USA [32, 33]. The results show variations between -0.15 and -0.37 for the different regions. In this study, we assume an elasticity of -0.25 for both inputs.

Given all assumptions and existing data, the estimated parameter values in the inverted demand function for each input are as reported in Table 2.

These functions provide information about p^{cr} and p^{crs} for each input at certain levels of X^{cr} and X^{crs} respectively. For example, the p^{cr} for nitrogen fertilizer when the supply is 92,000 tonnes, which implies a reduction by one half of its use in 2023 (Table S1 in Supplementary Material), is 3.45 euros/kg ($5.68 - 0.024 \times 92 = 3.45$). When the stock release compensates for this reduction in supply, the equilibrium price is the same as the BAU price before the crisis, i.e. $p^{crs} = p$, which amounts to 1.31 euros/kg. It can then be concluded that this stock disposal implies losses for its sellers, since its reduction in price

Table 2 Calculated parameters for inverted factor demand for agricultural inputs ($p = p^{max} - aX$) where X is measured in thousand metric tons

	p^{max} , euro/kg	a
Nitrogen fertilizer	5.68	0.024
Seeds	2.66	0.012
Protein feed	2.52	0.002
Pesticides:		
Herbicides	115.8	41.06
Fungicides	587.2	2435
Insecticides	1771	45,294
Diesel fuel	8.22	0.029

Source: Supplementary Material Section A

is relatively larger than the increase in input supply, i.e., $(1.31/3.45) < 0.5$.

Based on the estimates in Table 2, calculations are made of *PS*, *FS* and associated *NEVS* for all inputs but diesel fuel. The inverted demand function in Table 2 for diesel fuel only shows the demand by the agricultural sector, which constitutes a small share of the total diesel demand in Sweden. Therefore, calculations are only made of the impacts on farmers of changes in the supply of fossil diesel fuels.

Stockpiling costs

Stockpiling costs consist of three main components: (i) investment cost for storage facilities, (ii) operating costs and (iii) rental cost of the capital tied up in the stock. The investment cost in a warehouse building differs between the inputs and is determined by the assumed size and type of the building and its technical life length. Operational costs include the costs of loading machines, labour and waste due to, for example, losses in quality and/or quantity in the input during storage. The costs of rent reflect the opportunity cost of the capital tied up in the stock, i.e., the return of the same amount of capital in alternative funds or investments. The calculations of these costs are explained in detail in Supplementary Material Section B and are only briefly presented in the following.

A suitable storage building is assumed to be the same for fertilizers, seeds, protein feed and pesticides. The building covers an area of 5000 m² with a height of 5 m to allow for loading the inputs by trucks. Storage of pesticides requires that the building be isolated and equipped

with an air source heat pump system, as the storage of pesticides must be frost-free [34]. Stockpiling of diesel fuel is assumed to be made at the farm level in a tank of a certain volume.

Calculating operating costs and capital rental costs are common to all inputs. A loading machine is assumed to be needed for a few hours per week at a given cost per hour. A flat-rate deduction is made for costs of waste corresponding to 1% of the inventory value. Personnel costs are estimated to be relatively similar to those of cooperative grain companies that buy products and sell agricultural inputs. The interest rate on the capital value of the stock amounts to 3%, which reflects the rate of growth in the Swedish economy over a 20-year period [35].

The costs are expressed in euros/tonne. These costs differ between the inputs due to different storage options and weight per area of storage capacity (Supplementary Material Section B). The calculated storage cost per tonne input is reported in Table 3. We also express the total unit cost of stockpiling as a percentage of the price in 2023 for each input. This reflects the ‘insurance’ premium for covering damages in a crisis event.

There are large differences in cost per tonne between the inputs, being lowest for protein feed and highest for pesticides. Common to all inputs is the relatively high capital cost for investment in storage facilities and the opportunity cost of the capital invested in the emergency stock.

Results

Given the data presented in Sect. 4, calculations are made for the seller and farmer surplus, the *NEVS* and the number of years for which the *NEVS* is positive for each input when the supply of the input is reduced by 50%. This reduction level is motivated by the trade disruptions that Sweden experienced during World War II when imports of essential inputs and foods were reduced by one half [36]. Without any emergency stock release, the prices would increase by at least 167% from the price before the crisis (Table S3 in the Supplementary Material). Sellers of inputs would face a net gain for all inputs but pesticides and the farmer surplus would be reduced for all inputs.

Impacts of stock disposal in the reference case are calculated by assuming that the size of the stock of each input corresponds to the reduction in the supply. This implies that the equilibrium price with the stock disposal is the same as the price before the crisis. There will, therefore, not be any dispersal impacts affecting the prices of food for consumers. This is an argument for the simple calculations of production value by means of input demand functions in this study. An additional assumption is that sellers are not compensated for any losses of stock releases.

Table 3 Stockpiling costs for different inputs in euros/tonne and year and % of *p*

	Nitrogen fertilizer	Seeds	Pro- tein feed	Pesticides	Die- sel fuel
Capital cost of investment	33.8	23.9	23.9	1938.8	83.8
Operating costs:	53.1	12.6	12.5	1191.4	32.9
Maintenance	2.9	2.1	2.1	167.2	19.7
Heating	0.6	0.4	0.4	95.0	
Wood chip for dryer					
Electricity	0.2	0.2	0.2	3.6	
Loading	2.6	1.8	1.8	452.3	
Waste	39.5	5.2	5.1	301.3	10.3
Labour	7.3	2.9	2.9	172.0	2.9
Interest on working capital	13.2	15.7	15.4	927.6	30.9
Total	100.2	52.2	51.9	3658.6	147.5
Total cost (% of price <i>p</i>)	8	10	10	5	14

Source: Supplementary Material Section B

However, several assumptions have been made regarding the data retrieval. Therefore, sensitivity analyses have been carried out with changes in the parameter values underlying the estimates of the production values of inputs and costs of stockpiling. In addition, calculations have been made for changes in the more politically oriented assumptions on the magnitude of supply decrease, choice of input stock disposal and compensation payments to sellers.

Reference case

Assuming that the stock corresponding to a 50% reduction in the supply is built up in one year and emptied during the next year, the estimated *NEVS*s vary considerably between the inputs (Table 4).

Sellers of all inputs but pesticides would prefer the stock is not released due to the relatively large price reduction. The supply in the crisis without the stock is 0.5 of the supply with the stock and *PS* is then positive only when the quotient between the price with and without the stock disposal exceeds 0.5 (Eq. (4) in Sect. 3). This only occurs for pesticides and the quotient for other inputs is approximately 0.3 (Table S3 in the Supplementary Material). The calculated sellers' losses correspond to 25% of the turnover of fertilizers and to 33% of the turnover of seed and protein feed (Tables S2-S3 in the Supplementary Material). As expected, farmers gain from the disposal of all emergency stocks due to the lower prices. This gain is considerable when compared with the gross value added from the agricultural sector, which amounted to approximately 2,068 million euros in 2023 [37]. The net budget revenues are negative due to the payment of the stockpiling cost, which varies between 3 and 27 million euros for the different inputs.

The assumption that the stock is used the year after the build-up is unlikely to hold. It is more likely that the crisis occurs after a number of years. This means that the sum of the costs of stocks across a number of years increases and the value decreases due to the discount rate (Eq. (7) in Sect. 3). Calculations of the *NEVS* has, therefore, been made for two different time periods between the inventory build-up and the crisis event, 5 and 10 years. In addition, estimates have been made for the number of years before the *NEVS* becomes negative (Table 5).

The value of stocks of seeds and protein feed is reduced most rapidly due to their relatively high storage costs. In order to obtain a positive *NEVS* for protein feed, the crisis should occur within 13 years.

Sensitivity analyses

In order to assess the effects of changes in parameter values, calculations have been made for deviations of 50% from the reference values of price elasticity of demand in absolute terms, stockpiling costs and discount rate. A

Table 4 Stockpiling cost, seller and farmer surplus (*PS* and *FS*) and the net economic value of emergency stocks (*NEVS*) of a 50% reduction in the supply of different inputs (million euros)

Input	Stockpiling cost	PS	FS	NEVS
Nitrogen fertilizer	10	-80	301	211
Seeds	5	-48	143	91
Protein feed	27	-265	794	502
Pesticides	3	4	81	82
Diesel fuel	23		617	593

Table 5 The *NEVS*^T for T=5 and T=10 years after the initial stock build-up and the number of years until the *NEVS*=0 (discount rate, 3%)

Input	NEVS5 Million euros	NEVS10 Million euros	Years before NEVS=0
Nitrogen fertilizer	126	65	15
Seeds	50	21	13
Protein feed	268	102	13
Pesticides	52	30	19
Diesel fuel	403	265	17

decrease (increase) in the price elasticity of, for example, nitrogen then implies a change from the reference elasticity of 0.3 to 0.15 (0.45). The results show large variations in the impacts on the *NEVS* of such changes in price elasticities (Fig. 1).

Two main observations can be made from the results presented in Fig. 1. One is the minor impact of the changes on storage costs, which is explained by the small share of the stockpiling cost compared with the value of the stocks. The second observation is the differences in the impacts of price elasticities on the *NEVS* between the inputs. For diesel fuel, the *NEVS* is 388 and 1,210 million euros for the high and low price elasticity in absolute terms respectively. These differences are enhanced for larger deviations, where a 75% deviation from the reference elasticities can give a fourfold increase in *NEVS* for diesel fuel (Table S5 in Supplementary Material).

However, the *NEVS* hides the allocation of impacts between *PS* and *FS* (Tables S4-S5 in Supplementary Material). Reductions in price elasticities of demand for protein feed generate the largest, but opposite, stock disposal impacts on sellers and farmers. A decrease in elasticity from 0.3 in absolute terms to 0.15 implies a large increase in the equilibrium price without stock disposal. The sellers' loss from a stock release is then three times the loss in the reference case and amounts to 794 million euros due to the corresponding decrease in price, which is not compensated by the higher sales volume. The farmers' gain from the stock disposal is doubled and amounts to 1,588 million euros due to the lower price. It can also be noted that an increase in the price elasticity of nitrogen fertilizers with 75% in absolute terms does not

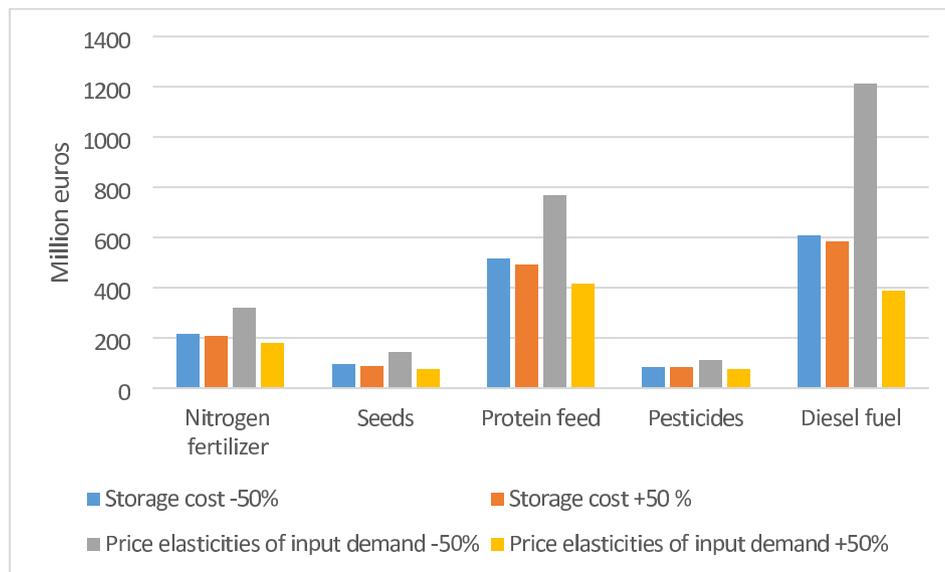


Fig. 1 Net economic value of stocks (*NEVS*) when storage cost and price elasticities of demand deviate by 50% from the reference values (million euros) (Table S4 in Supplementary Material)

Table 6 Stock releases where sellers' losses are zero without a compensation payment and with a budget neutral payment; share of input reduction, farmer surplus (*FS*) and net economic value of stockpiling (*NEVS*) (million euros)

Input	No compensation payment:				Budget neutral ^c :		
	Share ^a FS	NEVS	Budg. rev. ^b		Share ^a FS	NEVS	
Nitrogen Fertilizers	0.6	157	151	44	0.78	218	200
Seeds	0.5	60	57	19	0.70	90	87
Protein feed	0.5	331	317	106	0.70	500	487

^aStock release as a share of the exogenous supply reduction by 50%; ^bBudget incomes from sales of inputs at the equilibrium input price minus costs of storage and purchases of the input at the price without crisis; ^cBudget net revenues are zero

generate losses to the sellers from the stock release (Table S5 in Supplementary Material).

Changes in the discount rate impact the number of years for which the $NEVS > 0$. A decrease (increase) in the discount rate increases (reduces) the present value of both stockpiling costs and the value, but the change in the value dominates due to the relatively low stockpiling costs. Sensitivity analysis where the discount rate deviates by 50% from 3% changes the number of years when the $NEVS > 0$ at the most with three years which occurs for pesticides and diesel fuel (Table S4 in Supplementary Material). A zero discount rate would increase the number of years at the maximum with seven years and a discount of 7% would reduce the number of years with a maximum of five years (Table S5 in Supplementary Material).

Regarding the more politically oriented assumptions, no compensation payments were made to the sellers of inputs for their losses from stock disposals and the farmers were fully compensated for their losses from the exogenous supply decrease. Both sellers and farmers make positive gains from the stock disposal of pesticides, but sellers face losses from the disposal of nitrogen

fertilizers, seeds and protein feed. Lower disposal levels of these inputs will increase the price p^{crs} , which reduces farmers' surplus and sellers' losses. Successive increases in the stock disposal from zero to decreasing the entire supply show that the break-even when PS switches from positive to negative differs between the inputs (Table S6 in the Supplementary Material).

Sellers' losses from stock releases can be avoided in three ways. One is to compensate for the losses in the reference case displayed in Table 4, which will give negative budget net revenues. Another option is to adjust X^s to the level where losses are zero without compensation payments, which will generate positive budget net revenues. The third option is to implement a budget neutral mechanism where the level of X^s is chosen so that all budget revenues are used to compensate sellers' losses. The calculations show that the budget neutral policy generates larger $NEVS$ than the budget revenue raising mechanism when the exogenous input supply decrease is 50% (Table 6).

The share of disposal without compensation payments differs slightly between the inputs, but FS , the $NEVS$ and budget revenues show large differences and are highest

for protein feed. The pattern of impacts is similar to the budget neutral compensation payment, but at higher levels of the stock release shares, *FS* and the *NEVS*. Both *FS* and the *NEVS* are lower than in the reference case, farmers' gains from the stock release are reduced by up to 294 million euros (protein feed), but the *NEVS* is only slightly changed due to the losses avoided for the sellers.

However, stock releases below the input supply decrease generate higher production costs for farmers in Sweden with dispersal effects in the food sector and associated impacts on consumer prices. The magnitude of these effects depends on whether consumers can adjust their consumption and shift to imported foods. Gren et al. [9] showed that the effect on consumers is negligible when they can increase consumption of imported foods. This will reduce demand for food produced in Sweden with associated losses for the farmers. When imports of food is limited, the demand for food produced in Sweden can increase. The sizes of these effects can only be calculated with a partial equilibrium model. Simple sensitivity analyses show that if the demand at the BAU input price increases by 25%, sellers' and farmers' surplus are positive for the same stock release as in the reference case for all inputs but nitrogen fertilizers (Table S7 in the Supplementary Material). In addition, the government's budget net revenues are positive since the equilibrium price of stocks exceed the storage cost plus the purchase cost.

Changes in the exogenous input supply imply similar impacts to changes in the share of stock disposal when this corresponds to decreasing the whole supply. A lower decrease in the exogenous supply implies a smaller effect on *FS* and associated reduction in the *NEVS* and vice versa. However, the effects on *PS* are less clear, since they depend on the decrease relative to the change in equilibrium prices. Calculations were made for decreases in the BAU supply of inputs by 25% and 75% instead of the decrease by 50% in the reference case. In the same vein as in the reference case, it was assumed that the stock disposals correspond to the supply decrease. A low supply reduction implies a low *NEVS* and vice versa (Table S8 in the Supplementary Material). For seeds, the *NEVS* is reduced by 69% compared with the reference case at the low supply reduction and increased by 95% at the high supply decrease. The *PS* is positive for nitrogen fertilizers at the high supply reduction, since the relative price decrease was lower than the relative supply increase from the stock disposal.

Discussion

The purpose of this study was to calculate the net economic value of emergency stocks for fuel, nitrogen fertilizer, seeds, plant protection and protein feed. The value was calculated as the difference in net income for sellers of inputs and farmers buying the inputs with and

without emergency stocks when the supply of the inputs is reduced. The simple conceptual analysis shows that farmers always make net gains when emergency stocks are used to increase the supply, while the effects are less clear for the sellers. Disposal of the emergency stock in a crisis event increases supply on the market, which reduces sellers' income due to the decrease in the equilibrium price, which is counteracted by the increased sales volume. It was also shown that a stock owner's budget net revenues can be positive and used to compensate any seller losses from a stock release. However, this result is not new in any way and has been shown conceptually in several studies [12, 38].

The more interesting issue is, therefore, the magnitude of impacts on the sellers' and farmers' profits from the disposal of the stock and the costs of emergency stocks, the calculations of which require data on the stockpiling cost and production value of each input. Such data were not available and a simplified analysis was, therefore, made based on expert information on the costs of stockpiling and on agricultural demand for inputs. The results of stock disposal when the supply decreases by 50% of each input showed considerable differences between the inputs. The net economic value of stock disposal ranged between 82 (pesticides) and 593 million euros (diesel fuel). The results also revealed that the gains for the farmers are largest and the losses for the sellers highest in the case of disposal of the stock of protein feed (794 and -265 million euros for farmers and sellers respectively). The farmers' gain then corresponded to 38% of the value added in the agricultural sector in 2023 and the sellers' losses to 33% of the gross value of sales. However, sensitivity analyses indicated that the results depend relatively much on the level of the price elasticities of input demand and the magnitude of the stock disposals. It was also shown that the net economic value of the stock disposals of all inputs decreases with the length of time between the build-up of the stock and the timing of the crisis, since storage costs accumulate over the years, while the value of the stock is realized in the event of a crisis.

It is difficult to compare our calculated *NEVS*s with results from other studies because similar calculations have not been made. A partial comparison can be made of the calculated value of the stocks with the estimates of the costs in the agricultural sector of a reduction in imports of nitrogen fertilizers, diesel fuel and pesticides without stock disposals by [9]. Gren et al. [9] used a partial equilibrium model, which accounted for the dispersal of impacts from primary producers to consumers in the food chain. Their results indicated decreases in firms' profits by 260, 100 and 600 million euros from a 50% reduction in the supply of fertilizers, pesticides and diesel fuel respectively. These costs are close to the calculated

values for farmers of stock disposals corresponding to a 50% reduction in supply in the present study. This amounted to 211, 82 and 593 million euros of fertilizers, pesticides and diesel fuel respectively. A comparison can also be made with the estimated stockpiling cost of 26 euros/tonne for feed by [6]. This is lower than the calculated cost of 52 euros/tonne of protein feed in the present study. The difference is due to the fact that [6] only considered investment cost in the storage building and not the management and rental costs of tied-up capital in the feed stock.

Needless to say, the results rest on several crucial assumptions in addition to the quantified parameter values in the cost and input demand functions. One is the definition of the value, which only includes the benefits to farmers and sellers of inputs, and not food security as such. Such a definition would require a well-defined value for food security, which is a challenge when considering the multidimensional facets of the concept [10, 11]. Sumsion et al. [39] identified 52 different definitions used in the literature and in practice. Regardless of the choice of metric and its operationalization, an efficient stockpiling strategy requires information on the impact of each input on the chosen food security metric. Such impacts cannot be calculated with the simple method used in this study, but require a partial equilibrium model of the agricultural and food sector [40].

Another crucial assumption was that reduction in supply occurs separately for one input at a time without dispersal impacts on other inputs and prices. This may be relevant when farmers are fully compensated for their loss in a crisis situation or for a short-term perspective when there are no adjustments that affect prices in the food chain. However, all inputs, such as fertilizers and pesticides, are complementary. This means that the use of several input goods decreases when, for example, the supply of fertilizer is reduced. This, in turn, changes the prices of these inputs and of foods. The final effects can only be calculated with a partial equilibrium model of the food sector. Another factor not considered in the present study is regional aspects. These may be important given that the degree of self-sufficiency is low in northern Sweden, where the transport costs of inputs and foods are high compared to the southern part [9]. All these limitations constitute interesting areas for further research.

Concluding comments

Despite the limitations of this study, the simple methodology suggested may be useful for policy makers if they are interested in a quick and immediate ex ante analysis of the costs and benefits of stockpiling agricultural inputs for an efficient contingency strategy for food security as envisaged by the European Commission [2]. Applying this method to the five agricultural inputs in

Sweden highlighted important issues in the management of stockpiling inputs. One is the challenge of the statement that ‘...commodities and food products, stockholding policies entail significant costs.’ ([2] page 7 row 8). The results for Sweden indicated that the stockpiling cost was relatively low and did not exceed 6% of the net economic value of stockpiling any input. It can also be noted that the sum of the estimated stockpiling costs of the five included inputs at a 50% reduction in supply amount to 68 million euros. This is well below the budgeted cost of 140 million euros per year for food security suggested by a Swedish governmental budget proposal [41]. Nevertheless, the considerable differences in stockpiling cost and release value between the inputs highlight the importance of prioritizing which inputs to store when there are active budget constraints.

The uneven allocation of the economic impacts of stock releases on sellers and farmers may call for compensation mechanisms to be in line with the CAP and Farm to Fork Strategy to ensure food supply is equitable [42]. While farmers always gain from stock releases the sellers can make losses. The present study described policy mechanisms where the net benefits of stock releases are positive for both sellers and farmers. We would then highlight a stockpiling option which has not received much attention in the EU strategy nor in the literature (review in [42]). A net zero loss of stock release to sellers and farmers could generate budget revenues to the stockowners from the turnover of the stock when the sales price exceeds the storage cost and price of purchasing the input. The associated incomes could be used to promote innovation in food security measures, such as biotechnologies for enhancing resilience in the EU agri-food system [43].

Our study also points to the importance of predicting the magnitude and timing of the supply decrease. It is difficult to make such predictions, which can be made only under conditions of uncertainty. For a risk averse society, this implies an additional value of the emergency stock, since it reduces the uncertainty in providing the input. The analysis and quantification of such a risk reduction or the ‘insurance’ values of emergency stocks of agricultural inputs are interesting topics for future research.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s40066-026-00604-0>.

Supplementary Material 1

Acknowledgements

We are much indebted to the editor’s and reviewers’ constructive comments on the manuscript.

Author contributions

IMG participated in the conceptualization, data curation, software, writing-original draft and formal analysis. HA participated in the conceptualization,

data curation, writing-review and editing. LJ did writing-review and editing. RK did project administration, participated in conceptualization and writing-review and editing. All authors read and approved the final manuscript.

Funding

Open access funding provided by Swedish University of Agricultural Sciences. The authors appreciate the funding of the project 'Economic analysis of food preparedness in Sweden' from the National Veterinary Institute (contract number 2020/197).

Data availability

Data are available upon request from the corresponding author.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 24 May 2025 / Accepted: 2 January 2026

Published online: 27 January 2026

References

1. EC (European Commission). Crisis preparedness – new EU stockpiling strategy. https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14636-Crisis-preparedness-new-EU-stockpiling-strategy_en Accessed 14 November 2025.
2. European Commission. 2021. Contingency plan for ensuring food supply and food security in times of crisis. COM/2021/689 final. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0689> Accessed 14 November 2025.
3. SOU (Swedish Government Official Reports). Livsmedelsberedskap för en ny tid. Betänkande av Utredningen om en ny livsmedelsberedskap. SOU 2024:8. <https://www.regeringen.se/rattsliga-dokument/statens-offentliga-utredningar/2024/02/sou-20248/> Accessed 1 December 2024.
4. Mauritzson S. Mat för miljoner. Statlig beredskapsplaneringen Inom livsmedelsområdet. Swedish Board of Agriculture; 2002.
5. MSB (Swedish Civil Contingencies Agency). Myndigheter och företag i samverkan för totalförsvaret. <https://www.msb.se/sv/publikationer/myndigheter-och-foretag-i-samverkan-for-totalforvaret-utvecklingsprojekt-for-forsorjning-g-av-varor-och-tjanster-i-kris-och-krig/> Accessed 4 December 2024.
6. Swedish Board of Agriculture. En robust livsmedelsförsörjning i kris och krig del 2 – beredskapslagring av insatsvaror till jordbruket. 2025. <https://www2.jordbruksverket.se/download/18.73587d8a198eca95c9d62eec/1758044541111/ovr757.pdf> Accessed 8 December 2025.
7. Saravia-Matus S, Paloma SG, Mary S. Economics of food security: selected issues. *Bio-based Appl Econ*. 2012;1:65–80. <https://doi.org/10.13128/BAE-10552>.
8. Smith V, Glauber J. Trade, policy, and food security. *Agric Econ*. 2019;51:159–71. <https://doi.org/10.1111/agec.12547>.
9. Gren IM, Jonasson L, Andersson H, Knutsson R. Economic impact and food security effects of trade disruptions in agricultural products for Sweden. *Agric Food Secur*. 2024;13:28. <https://doi.org/10.1186/s40066-024-00483-3>.
10. Santeramo FG. On the composite indicators for food security: decisions matter! *Food Rev Int*. 2015;31:63–73. <https://doi.org/10.1080/87559129.2014.961076>.
11. Teeuwen A, Meyer M, Dou Y, Nelson A. A systematic review of the impacts of food security governance measures as simulated in modelling studies. *Nat Food*. 2022;3:619–30. <https://doi.org/10.1038/s43016-022-00571-2>.
12. Kennedy L, Schmitz A, van Kooten GC. Food security and food shortage. *Encyclopedia of Food Security and Sustainability*, 2018. <https://doi.org/10.1016/B978-0-08-100596-5.22251>
13. van Kooten GC, Schmitz A. Commodity price stabilization: the price uncertainty case. *Can J Econ*. 1985;17:426–34.
14. Schmitz A, Chegini C. Societal gains from price stability: does risk matter? *Theor Econ Lett*. 2023;13:221–7. <https://doi.org/10.4236/tel.2023.132013>.
15. Wesseler J. Storage policies: stockpiling versus immediate release. *Journal of Agricultural & Food Industrial Organization*. 2020. <https://doi.org/10.1515/jafi-o-2019-0055>.
16. Gren IM, Andersson H, Jonasson L, Knutsson R. Food security and the value of game animals—a study of Sweden. *Eur J Wildl Res*. 2024;70:35. <https://doi.org/10.1007/s10344-024-01786-3>.
17. Gulbrandsen O, Lindbeck A. 1966 Jordbrukspolitiken mål och medel. Bonniers Boktryckeri, Stockholm, 2018. <https://www.ifn.se/media/cw1acifd/1968-o-gulbrandsen-a-lindbeck-jordbrukspolitiken-m%C3%A5l-och-medel-webb.pdf> Accessed 11 December 2024.
18. Folkesson L. Models for planning of the food supply in Sweden under emergency conditions. *Eur Rev Agric Econ*. 1973;1:79–95. <https://doi.org/10.1093/erae/1.1.79>.
19. Stenérus D, Odell A, Larsson P, Lindgren J. Beredskapslagring – En kunskapsöversikt om beredskapslagring som ett verktyg för ökad försörjningsberedskap i Sverige. FOI-R-4644-SE. 2019. <https://www.foi.se/rapportsammanfattning?reportNo=FOI-R-4644-SE> Accessed 21 November 2025.
20. World Bank. Using Public Food Grain Stocks to Enhance Food Security, Washington DC. 2012. <https://openknowledge.worldbank.org/handle/10986/11878> Accessed 11 December 2024.
21. MSB (Swedish Civil Contingency Agency). Civilt försvar mot 2030 – ett totalförsvaret i balans. 2022. <https://rib.msb.se/filer/pdf/30143.pdf> Accessed 4 December 2024.
22. SBA (Swedish Board of Agriculture). En robust livsmedelsförsörjning i kris och krig – beredskapsplanering av spannmål. <https://jordbruksverket.se/download/18.26ed604318e78be4a239740/1711619611832/En-robust-livsmedelsfor-sorjning%20i%20krig-kris-beredskapslagring-spannmal-tga.pdf> Accessed 12 December 2024.
23. Munnich-Vass M, Elofsson K, Gren I-M. An equity assessment of introducing uncertain forest carbon sequestration in EU climate policy. *Energy Policy*. 2013;61:1432–42. <https://doi.org/10.1016/j.enpol.2013.07.010>.
24. Nordin I, Elofsson K, Jansson T. Cost-effective reductions in greenhouse gas emissions: reducing fuel consumption or replacing fossil fuels with biofuels. *Energy Policy*. 2024;190:114138. <https://doi.org/10.1016/j.enpol.2024.114138>.
25. SOU (Swedish Government Official Reports). 2003:9 Skatt på handelsgödsel och bekämpningsmedel. 2003. <https://www.regeringen.se/contentassets/c788bb8cbf324bd084e0457b86cd8e31/skatt-pa-handelsgods-och-bekampningsmedel-kapitel-kapitel-1-6/> Accessed 8 December 2024.
26. Gonzales-Matinez A, Miaris G. Estimating demand elasticities of mineral nitrogen – some empirical evidence in the case of Sweden. *Stud Agricultural Econ*. 2024;126:108–16. <https://doi.org/10.7896/j.2804>.
27. Böcker T. R <>Finger 2017 A meta-analysis on the elasticity of demand for pesticides. *J Agric Econ* 68 518–33 <https://doi.org/10.1111/1477-9552.12198>.
28. Gren I-M. Cost efficient pesticide reductions: a study applied on Sweden. *Environ Resource Econ*. 1994;4:279–93.
29. Brännlund R. The effects on energy saving from taxes on motor fuels: the Swedish case. In: CERE Working Paper, 2013, vol. 6. <https://doi.org/10.2139/ssrn.2259658>
30. Tirkaso W, Gren I-M. Regional fuel price elasticities and impacts of carbon taxes. *Energy Policy*. 2020;144. <https://doi.org/10.1016/j.enpol.2020.111648>.
31. Aklilu A. Gasoline and diesel demand in the EU: implications for the 2030 emission goal. *Renew Sustain Energy Rev*. 2020;118:109530. <https://doi.org/10.1016/j.rser.2019.109530>.
32. Richardsson J, Ray D. Demand for feed grains and concentrates by livestock category. *Western Journal of Agricultural Economics*, 1978; July; 23–30.
33. Schmeltz C, Lee D. Rail regulatory reform and changing interregional competitiveness in the feed grain industry. *Cornell Agricultural Economic Staff Paper no. 88 – 11*, 1988. <http://publications.dyson.cornell.edu/research/researchpdf/sp/1988/Cornell-Dyson-sp8811.pdf> Accessed 18 December 2024.
34. Lyngson AS, Investeringskalkyl. December : Uppvärmning av lager. <https://lyngson.no/wp-content/uploads/2023/03/Investeringskalkyl.pdf> Accessed 20 2024.
35. National Institute of Economic Research. BNP per capita – en historisk jämförelse med åren framöver. Sweden: Stockholm; 2019.
36. Wijk J. Svarta börsen, samhällslojalitet i kris: livsmedelsransoneringarna och den illegala handeln i Sverige 1940–1949. *Almqvist & Wiksell International*. Stockholm, Sweden, 1992, pp. 17–19.
37. SBA (Swedish Board of Agriculture). Jordbruksekonomiska undersökningen 2014–2023, nyckeltal och standardiserade intäkter <https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksverkets-stat>

- istikrapporter/statistik/2025-10-23-jordbruksekonomiska-undersokningen-2014-2023-nyckeltal-och-standardiserade-intakter
38. Boardman A, Greenberg D, Vining A, Weimer D. Cost-benefit analysis—concepts and practice. 4th ed. Boston: Pearson Education; 2011.
 39. Sumsion R, June H, Cope M. Measuring food insecurity: the problem of semantics. *Foods*. 2023;12:1816. <https://doi.org/10.3390/foods12091816>
 40. Jonasson L. Beskrivning av SASM - En Ekonomisk optimeringsmodell över Jordbrukssektorn i Sverige. Rapport 6815. Swedish Environmental Protection Agency; 2018.
 41. Prop. 2024/25:01 Budgetpropositionen för 2025 - Utgiftsområde 23 Areella näringar, landsbygd och livsmedel. https://www.riksdagen.se/sv/dokument-och-lagar/dokument/proposition/budgetpropositionen-for-2025-utgiftsomrade-23_hc031d24/html/#page_60 Accessed 15 December 2024.
 42. Galanakis C, Daskalakis M, Galanakis I, Nehrey M, Spanou M, Vetsou A, et al. Landscape of policies, standards, approaches, and projects for EU food security: an overview. *Discover Food*. 2025;5:117. <https://doi.org/10.1007/s44187-025-00387-6>.
 43. European Innovation Council. Biotechnology driven low emission food and feed production systems https://eic.ec.europa.eu/eic-funding-opportunities/eic-accelerator/eic-accelerator-challenges-2025/biotechnology-driven-low-emission-food-and-feed-production-systems_en Accessed 21 November 2025.

Publisher's note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.