

I.9 Agricultural Sector Resilience Progress Indicator

Methodology, Implementation, and Future Development

Catarino, R., Dentener, F.

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Abstract

This technical report presents the conceptual and methodological foundations of the Agricultural Sector Resilience Progress Indicator, included in the Common Agricultural Policies (CAP) Performance Monitoring and Evaluation Framework (PMEF) as indicator I.9. The indicator is designed to assess the capacity of the European Union farming sector to withstand and adapt to climate-related stressors. It is composed of four policy-relevant sub-indicators covering production, income, water, and soil resilience. It evaluates both the current resilience status and progress over time, using 15-year reference (2001–2015) and evaluation (2007–2021) periods benchmarked against EU-27 performance distributions. This report details the methodological choices and interpretation of I.9, providing a transparent framework for its application and future refinement.

The primary purpose of the indicator is to serve as an early-warning system, i.e. flagging when performance across key resilience dimensions is regressing, stagnating, or progressing. To support this objective, a simple three-grade scoring system [0, 0.5, 1] was adopted, applied to each sub-indicator and aggregated into the composite index. This approach enables meaningful interpretation of shifts over time while facilitating communication with stakeholders. It avoids overemphasising minor rank differences and maintains flexibility in assessing broader trends in sectoral resilience.

The indicator is made operational through an interactive online dashboard that allows users to explore resilience trends across Member States and time. The report concludes with recommendations to enhance the I.9 framework, including the integration of additional indicators such as drought resilience and crop diversity, and emphasizes the strategic importance of diversification in mitigating farmers' exposure to climate and market shocks. As the framework continues to evolve, future improvements will focus on refining input data, enhancing statistical robustness, and expanding conceptual scope to better support EU climate adaptation and agricultural policy goals.

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Finally, we thank the JRC Competence Centre on Composite Indicators and Scoreboards (CC-COIN) for their independent methodological audit and constructive recommendations, which greatly enhanced the clarity, robustness, and transparency of the I.9 framework.

Authors

Rui Catarino, Frank Dentener. All authors are from the European Commission, Joint Research Centre (JRC), Unit D.5 – Food Security.

1. Introduction

In the context of agriculture, resilience is broadly defined as the capacity of agricultural systems to absorb, adapt, and transform in response to shocks and long-term stresses, while maintaining their essential functions and structure (Allen et al., 2019; Walker et al., 2004). From an EU policy perspective, resilience reflects the ability of farming systems to sustain productivity, economic viability, and ecosystem services under increasing climatic, environmental, and market pressures (Meuwissen et al., 2019; OECD, 2023). It thus encompasses both the capacity to withstand short-term shocks and the adaptive capacity to reorganise in response to long-term structural changes, ensuring the long-term sustainability and stability of food systems (Darnhofer, 2014).

The resilience of the EU agricultural production system is essential for food security, economic stability, and environmental sustainability (Hristov et al., 2024; Meuwissen et al., 2020). This has become a central focus in major international policies, including the European Green Deal (EC, 2019), as climate change and other factors, such as market dependencies and financial pressures on farmers, increasingly threaten agricultural productivity (Toreti et al., 2022). More frequent extreme weather events further exacerbate these challenges, intensifying the economic strain on farmers and jeopardizing the stability of agricultural systems (Zampieri et al., 2020a). Therefore, evaluating the resilience of the agricultural sector is essential for assessing its capacity to maintain critical functions, such as fair economic returns, and services including sustainable food production (Buitenhuis et al., 2020) and biodiversity conservation (Dardonville et al., 2020). To support this evaluation, improved data availability and new resilience metrics are needed to assess vulnerabilities and guide effective strategies (Allen et al., 2019; ECA, 2022; Jones et al., 2021).

The Common Agricultural Policy (CAP) defines a performance monitoring and evaluation framework (PMEF) that includes the Agricultural Sector Resilience Progress Indicator (I.9/C.45¹, henceforth referred to as I.9) to assess resilience progress within the EU agricultural sector and across individual member states. A multidimensional perspective underpins the I.9 framework, which evaluates both the **status** (current capacity) and **progress** (temporal change) of resilience in the agricultural sector.

This indicator synthesizes the status and progress of various factors affecting resilience and is specifically designed to monitor and identify elements that enhance resilience, particularly in response to climate change. By highlighting strengths and weaknesses, I.9 guides policy and management decisions to bolster resilience. It enables policymakers to assess how well the sector can adapt to and recover from mainly climate-related stresses, but also from other market and socio-economic disturbances, thereby supporting long-term productivity and stability. Identifying areas where member states may need improvement, I.9 also facilitates targeted interventions aimed at strengthening resilience for current and future generations and driving long-term transformational changes in response to climate and other disturbances.

The **I.9 indicator** was developed by the **European Commission's Joint Research Centre (JRC)** in close collaboration with **DG AGRI**, under the *CORES4AGRI Administrative Arrangement*. This

¹ In the CAP Performance Monitoring and Evaluation Framework (PMEF), "I" denotes an Impact Indicator, while "C" denotes a Context Indicator. The Agricultural Sector Resilience Progress Indicator is therefore identified as I.9 (Impact) and C.45 (Context) within the PMEF nomenclature. For more information please see: https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cmef_en

collaboration builds on the JRC's long-standing expertise in agricultural resilience assessment, indicator design, and science-for-policy reporting, ensuring both scientific rigour and policy relevance. The indicator's methodology and dashboard have been designed to provide policymakers and analysts with a harmonised, transparent framework for tracking resilience progress within the CAP PMEF.

In this context, the primary purpose of I.9 is to serve as an early-warning system - flagging when performance across key resilience dimensions is regressing, stagnating, or progressing. It does not intend to rank countries' resilience with precision. To support this objective, a simple three-grade scoring system [0, 0.5, 1] was adopted, applied to each of its sub-indicators and aggregated into the composite index. This approach enables meaningful interpretation of shifts over time while facilitating communication with stakeholders. It avoids over-emphasising minor rank differences and maintains flexibility in assessing broader trends in sectoral resilience.

This technical report is organised into several sections. Section 2 presents the conceptual foundations and policy rationale behind the development of the I.9 framework, highlighting its role in assessing and monitoring resilience within the agricultural sector. It also provides summary results, which will be explained in further sections. Section 3 provides detailed examination of the four sub-indicators, each of which is explored in terms of its motivation, methodological underpinnings, and contribution to the composite I.9 indicator. The subsequent section 4 introduces the I.9 dashboard, an interactive platform that enables users to visualise both aggregated resilience scores and individual sub-indicator values across spatial and temporal dimensions. The technical report concludes with a summary of the key findings and reflections on future directions, including proposed refinements to the I.9 framework and the integration of additional indicators to improve the robustness and relevance of resilience assessments considering evolving climatic, ecological, and economic challenges.

2. The Agricultural Sector Resilience Progress Indicator

The Agricultural Sector Resilience Progress Indicator (I.9/C.45) is a key metric within the CAP PMEF for assessing the capacity of each EU Member State, and the EU-27 collectively, to sustain and strengthen its farming systems under accelerating climatic change. By combining data already collected through the PMEF with complementary datasets from Eurostat, the Joint Research Centre (JRC) and the European Environment Agency (EEA), the indicator consolidates heterogeneous information into a policy-relevant, but easily interpretable, resilience score. This score enables policymakers to understand how well the sector can adapt to and recover from climate-related stresses. By highlighting areas needing improvement, I.9 supports the design of targeted interventions and the promotion of sustainable practices that safeguard long-term productivity and socio-economic stability across the Union.

2.1. Two complementary pillars of the resilience indicator: status and progress

The I.9 indicator distinguishes two complementary pillars, **status and progress**, to give a more detailed picture of resilience. The **status** measures the sector's resilience capacity at a given period in time, capturing both its strengths and vulnerabilities. While **progress** quantifies changes or improvements in resilience from the reference period to the evaluation period, thereby revealing how far the sector has adapted to emerging climatic and economic pressures. Both pillars are evaluated using the same methodology over **15-year periods**. In the current release, the reference period spans 2001–2015, while the evaluation period covers 2007–2021. This design ensures full methodological consistency between periods while allowing resilience to be tracked over time. The 15-year timeframe aims to capture longer-term trends and signals in climate variability, while still allowing to identify resilience responses to both gradual shifts and episodic extremes (Forster et al., 2021). The 15-year period also allows to identify resilience changes due to recent policy and technological shifts.

2.2. Overview of the four resilience sub-Indicators contributing to the composite indicator.

Within I.9, agricultural resilience monitoring is operationalised through one financial and three bio-physical sub-components, each reflecting a different dimension of resilience. The first bio-physical sub-component is the **Agriculture Production Resilience index (APRi)** which measures the stability in cereal production, indicating the reliability of production under intensifying weather variability (Zampieri et al., 2020b). The financial component is covered by the **Agricultural Factor Income Resilience index (AFIRi)** which quantifies the economic stability and income resilience of real factor income per annual work unit (AWU), derived from the PMEF C.25/I.3 indicator (Eurostat, 2025b). AFIRi indicates the sector's ability to absorb revenue shocks and sustain livelihoods (Sauer and Antón, 2023). The second bio-physical sub-component, **Water Resilience index (WRi)**, applied the Water Exploitation Index Plus (PMEF C.38/I.17; (Eurostat, 2025d) to measure regional aspects of seasonal pressure on renewable water resources, indicating irrigation- driven hydrological stress (Bisselink et al., 2020; De Roo et al., 2023). Finally, the **Soil Resilience index**

(SRI) tracks trends in soil-organic-carbon stocks, a key determinant of the soil's capacity to buffer environmental stressors and support agro-ecosystem services (Lugato et al., 2018).

These four sub-indicators were selected based on their policy relevance, methodological robustness and EU-wide data availability, forming a modular framework that can be expanded as new data and metrics emerge.

3. Methodology

The methodology involves **comparing an evaluation period (2007–2021) with a reference period (2001–2015)**, each spanning 15 years. These periods, chosen sufficiently long to appreciate statistically relevant changes in impacts of climate variability caused by one or more events. The sub (contributing) indicators and the composite indicator are measured using two metrics: Status and Progress.

Resilience status in each period is benchmarked against the EU-27 distribution fixed from the reference period, using quartile-based cut-offs: values below P37.5 receive a score of 0; values between P37.5 and P62.5 (the inner-quartile band around the median) receive 0.5; and values above P62.5 receive 1. Progress is then derived by comparing status in the evaluation period with status in the reference period: deterioration scores 0, stability within the tolerance band scores 0.5, and improvement scores 1. The tolerance band prevents over-interpretation of minor fluctuations and operationalises the concept of “stable conditions”, i.e. without relevant change compared to previous period. The scores for the four sub-indicators are summed, each contributing equally, to produce composite I.9 Status and Progress (table 3) values ranging from 0 (lowest resilience) to 4 (highest resilience).

Robust assessment of the four I.9 sub-indicators demands a transparent statistical workflow that traces every step from raw data ingestion through transformation, normalisation, and scoring. Two complementary methodological approaches underpin this workflow. The first, applied to AFIRi and APRI, relies on **variability-based stability metrics**, i.e. long-term series are detrended and the residual variability is converted into a resilience score. The second, used for WRi and SRi, adopts a **threshold-exceedance framework**, benchmarking monthly observations at regional resolution against scientifically grounded limits. The following subsections detail the computations for each sub-indicator and show how these methods feed into the Status and Progress scores.

The results for the four sub-indicators are presented in Table 2 for the reference period and in Table 3 for the evaluation period. High status or progress scores, either for an individual sub-indicator or for the aggregated I.9 headline value, signal a strong capacity to withstand and adapt to shocks, including climate impacts, whereas persistently low scores flag domains where substantive improvement is required.

Table 1. Composite I.9 Resilience Status and Progress Scores for EU Member States.

Member state	Reference (2001–2025)	Evaluation (2007–2021)	
	Status	Status	Progress
Austria	2.5	3	2
Belgium	2.5	2.5	1.5
Bulgaria	0.5	0.5	2.5
Cyprus	1	1	1.5
Czechia	1.5	2.5	3
Germany	2	2	3
Denmark	2	2	1
Estonia	2	2	0.5
Greece	1.5	1.5	0.5
Spain	1	1	2
Finland	4	2.5	1
France	2.5	2.5	1
Croatia	2	3	3
Hungary	0.5	1	3
Ireland	3	3	1.5
Italy	2	2	2.5
Lithuania	1.5	1.5	2
Luxembourg	3	3	2.5
Latvia	2	2	1.5
Malta	1.5	1.5	1
Netherlands	4	4	1.5
Poland	2	2.5	3
Portugal	1	1.5	3
Romania	1	1.5	3
Sweden	3.5	2.5	1
Slovenia	2.5	3.5	2.5
Slovakia	1.5	1.5	2.5
European Union (27)	2.5	2.5	2.5

This table presents the composite I.9 status and progress scores for each EU27 Member State, derived by summing the individual scores of the four sub-indicators: Agricultural Production Resilience Index (APRI), Agricultural Factor Income Resilience Index (AFIRI), Water Resilience Index (WRI), and Soil Resilience Index (SRI). Each sub-indicator contributes equally to the composite, resulting in values ranging from 0 (lowest resilience) to 4 (highest resilience). Status scores are provided for both the reference period (2001–2015) and the evaluation period (2007–2021). Progress is defined as the change in composite status between the two periods. A higher I.9 progress score indicates greater improvement in agricultural resilience over time. EU27 values are calculated as unweighted averages across Member States.

Source: JRC

Table 2. Sub-indicator Status Scores for the Reference Period (2001–2015) across EU Member States.

Member state	APRI	AFIRi	Wri	SRi
Austria	1	0.5	0.5	0.5
Belgium	1	0.5	0	1
Bulgaria	0	0.5	0	0
Cyprus	0	1	0	0
Czechia	0.5	0.5	0.5	0
Germany	1	0	0.5	0.5
Denmark	1	0	0	1
Estonia	0	0	1	1
Greece	0.5	1	0	0
Spain	0	1	0	0
Finland	1	1	1	1
France	1	1	0	0.5
Croatia	0	0	1	1
Hungary	0	0	0.5	0
Ireland	0.5	0.5	1	1
Italy	1	1	0	0
Lithuania	0	0	1	0.5
Luxembourg	1	0	1	1
Latvia	0.5	0	1	0.5
Malta		1	0	0.5
Netherlands	1	1	1	1
Poland	1	0	1	0
Portugal	0	1	0	0
Romania	0	0	1	0
Sweden	0.5	1	1	1
Slovenia	0.5	0.5	0.5	1
Slovakia	0	0.5	0.5	0.5
European Union (27)	1	1	0	0.5

For each member state, the Status scores are presented for the four sub-indicators of agricultural resilience: Agricultural Production Resilience Index (APRI), Agricultural Factor Income Resilience Index (AFIRi), Water Resilience Index (WRI), and Soil Resilience Index (SRi). Resilience status in the reference period is benchmarked against the EU-27 distribution obtained from the reference period, using percentile cut-offs: values below P37.5 receive a score of 0; values between P37.5 and P62.5 (the inner-quartile band around the median) receive 0.5; and values above P62.5 receive 1.

Source: JRC

Table 3. Sub-indicator Status and Progress Scores for the Evaluation Period (2007–2021) across EU Member States

Member state	APri		AFIRi		WRi		SRi	
	Status	Progress	Status	Progress	Status	Progress	Status	Progress
Austria	1	0.5	1	0.5	0.5	0.5	0.5	0.5
Belgium	1	0	0.5	0.5	0	0.5	1	0.5
Bulgaria	0	1	0.5	0.5	0	0.5	0	0.5
Cyprus	0	0	1	1	0	0	0	0.5
Czechia	1	1	1	1	0.5	0.5	0	0.5
Germany	1	1	0	1	0.5	0.5	0.5	0.5
Denmark	1	0	0	0	0	0.5	1	0.5
Estonia	0	0	0	0	1	0.5	1	0
Greece	0.5	0	1	0	0	0	0	0.5
Spain	0	1	1	0	0	0.5	0	0.5
Finland	0.5	0	0.5	0	0.5	0.5	1	0.5
France	1	0	1	0	0	0.5	0.5	0.5
Croatia	0.5	1	0.5	1	1	0.5	1	0.5
Hungary	0	1	0.5	1	0.5	0.5	0	0.5
Ireland	0.5	0	0.5	0.5	1	0.5	1	0.5
Italy	1	1	1	0.5	0	0.5	0	0.5
Lithuania	0	1	0	0	1	0.5	0.5	0.5
Luxembourg	1	0.5	0	1	1	0.5	1	0.5
Latvia	0	0	0.5	1	1	0.5	0.5	0
Malta			1	0.5	0	0	0.5	0.5
Netherlands	1	0	1	0.5	1	0.5	1	0.5
Poland	1	1	0.5	1	1	0.5	0	0.5
Portugal	0.5	1	1	1	0	0.5	0	0.5
Romania	0	1	0.5	1	1	0.5	0	0.5
Sweden	0	0	0.5	0	1	0.5	1	0.5
Slovenia	1	1	0.5	0.5	1	0.5	1	0.5
Slovakia	0	0.5	0.5	1	0.5	0.5	0.5	0.5
European Union (27)	1	1	1	0.5	0	0.5	0.5	0.5

For each member state, the Status and Progress scores are presented for the four sub-indicators of agricultural resilience: Agricultural Production Resilience Index (APri), Agricultural Factor Income Resilience Index (AFIRi), Water Resilience Index (WRi), and Soil Resilience Index (SRi). Resilience status in the reference period is benchmarked against the EU27 median: values below this median receive a score of 0, values within a JRC-defined tolerance band receive 0.5, and values above the median receive 1. Progress is calculated by comparing status in the evaluation period (2007–2021) with the reference period (2001–2015): 0 indicates deterioration, 0.5 stability, and 1 improvement.

Source: JRC

3.1. Agriculture Production Resilience Index (APRi)

The APRi quantifies the annual stability of national cereal output reported to Eurostat (Eurostat, 2025c). Cereals (grains, other cereals, and some fodder crops), representing around 9.4 % of the economic value of EU's total agricultural output are, after vegetables, the largest crop category in terms of economic value in the EU. While adaptation and management practices can enhance resilience, climate-driven yield variability, market dynamics, and spatial shifts in crop area continue to challenge production stability.

For this reason, aggregated cereal crop production - defined as the sum of all cereal types produced annually, as reported by Eurostat - rather than average yield, is used to assess resilience because it offers a more comprehensive view of system dynamics. This approach captures shifts in crop area and accounts for regional yield variability driven by differences in soil and climate conditions. It also reflects changes within cereal types, such as switching to higher-value varieties, while allowing lower yields in one region to be offset by higher yields elsewhere. Focusing on total national production aligns with ecological resilience principles by emphasising system-wide productivity, making the metric more relevant for policy and management strategies aimed at strengthening the overall resilience of cereal production systems.

APRi captures these dynamics, providing a comprehensive measure of crop system resilience across Member States and the EU-27, and offering large-scale insights into the capacity of agricultural systems to maintain productivity under variable environmental conditions.

Low APRi values signal the need for improved agricultural practices and policies to enhance resilience and ensure long-term productivity. Geographic and climatic factors significantly influence production resilience, necessitating tailored strategies to address regional challenges and optimize agricultural performance across diverse environments.

The supporting datasets for this sub-indicator are documented in excel file in **Supplementary File 1 – APRi**. The first *tab (raw_data)* contains the input data extracted from Eurostat's crop production statistics dataset ([apro_cpsh1](#)) on 10/02/2025. Subsequent tabs correspond to each processing step.

Step 1 - Detrending and normalising observed production data

The first step detrends and normalises the production data to separate short-term fluctuations from long-term structural trends. For each Member State m , a third-order polynomial is fitted to the annual cereal-production time series (Equation 1):

Equation 1. Polynomial detrending of production time series

$$\hat{P}_{m,t} = a + bt + ct^2 + dt^3$$

Where $\hat{P}_{m,t}$ is the fitted production value in year t , and a, b, c, d are the estimated polynomial coefficients. Then, the observed production values $P_{m,t}$ are detrended and normalised by dividing them by the corresponding fitted values, yielding the dimensionless residual time series (Equation 2):

Equation 2. Normalisation of observed production values

$$R_{m,t} = \frac{P_{m,t}}{\hat{P}_{m,t}}$$

Values of $R_{m,t}$ close to 1 indicate consistency with the long-term trend, whereas deviations capture inter-annual variability driven by shorter-term stressors such as extreme weather events. This normalisation also ensures comparability across Member States with differing absolute production levels. We acknowledge that long-term trends may also reflect shifts in agro-management practices, production systems or land-use changes, which may be influenced by change in climate but also by economic, market, and policy factors. However, fully disentangling these dynamics within the indicator remains challenging.

Step 2 - Stability calculation

Then, for each Member State m and 15-year period p , **stability** is calculated as the inverse of the squared standard deviation of $R_{m,t}$ (Equation 3).

Equation 3. Calculation of stability score (inverse variance method)

$$S_{m,p} = \frac{1}{\sigma_{m,p}^2}$$

This formulation yields a dimensionless stability score, with higher values indicating greater resilience in cereal production due to lower interannual variability. In practice, scores typically range from below 5 (high variability, low resilience) to above 400 (high stability, high resilience), allowing for clear cross-country comparisons within the I.9 framework.

Step 3 - Determine percentile thresholds across Member States

To classify stability scores in a comparative, cross-country framework, five percentiles $\{P_{12.5}, P_{25}, P_{37.5}, P_{62.5}, P_{87.5}\}$ thresholds are calculated from the distribution of stability values $S_{m,p}$ across all 27 Member States and the EU-27 as a whole. This calculation is performed separately for each period (reference and evaluation). These percentiles define discrete bands used to categorise countries by relative resilience within the EU context. The median of the EU-27 MS' values from the reference period are used as the benchmark for comparison.

Step 4 - Assign Resilience Status

Each Member State m is assigned a **Resilience Status Score** for each period p based on its national stability value $S_{m,p}$ using a three-level classification that distinguishes high, average, and low resilience relative to the EU-wide distribution in the reference period:

Equation 4. Classification of resilience status based on percentile thresholds

$$Status_{m,p} \begin{cases} 1 & \text{if } S_{m,p} > P_{62.5} \\ 0 & \text{if } S_{m,p} < P_{37.5} \\ 0.5 & \text{if } P_{37.5} \leq S_{m,p} \leq P_{62.5} \end{cases}$$

Step 5 - Assign Resilience Progress

To evaluate how national stability has evolved between the reference and evaluation periods, a **progress ratio** is calculated for each Member State:

Equation 5. Calculation of progress ratio between evaluation and reference periods

$$P_m = \frac{S_{m,eval}}{S_{m,ref}}$$

Where $S_{m,ref}$ and $S_{m,eval}$ are the stability values in the reference (2001–2015) and evaluation (2007–2021) periods, respectively. **Resilience Progress** is then scored using a symmetric tolerance band (table 4) of $\delta = 0.10$ (i.e. $\pm 10\%$) around a neutral change (ratio = 1):

Equation 6. Evaluation of resilience progress using tolerance bands

$$Progress_{m,p} \begin{cases} 1 & \text{if } P_m > 1 + \delta \\ 0 & \text{if } P_m < 1 - \delta \\ 0.5 & \text{if } 1 - \delta \leq P_m \leq 1 + \delta \end{cases}$$

This tolerance band reflects a meaningful shift, i.e. a proxy for interpreting significant changes, in the magnitude and/or frequency of production fluctuations between the two periods.

Table 4. Component-specific tolerance bands (δ) used to score Resilience Progress.

Component	Tolerance band (δ)
Agricultural Production Resilience Index (APRI)	0.10
Agricultural Factor Income Resilience Index (AFIRi)	0.10
Water Resilience Index (WRI)	0.01
Soil Resilience Index (SRI)	0.01

Note: These JRC-defined tolerances delimit the “stable conditions” band (i.e., no relevant change between periods) for each I.9 component. They are used to classify change as deterioration ($1 - \delta \leq P_m$), stable ($1 - \delta \leq P_m \leq 1 + \delta$), or improvement ($P_m \leq 1 + \delta$), with P_m is the progress ratio for each Member state. The tolerance band represents a meaningful shift threshold and serves as a proxy for interpreting significant changes in the magnitude and/or frequency of the respective component values between the two periods.

Source: JRC

3.2. Agricultural Factor Income Resilience Index (AFIRi)

The **AFIRi** quantifies the annual stability of real (i.e., deflated) agricultural factor income per AWU, delivering a policy-relevant indicator of the sector’s ability to sustain livelihoods and maintain

economic performance under external shocks. Real agricultural factor income reflects the total income generated by the agricultural sector to remunerate both **external production factors** (e.g. wages, capital, and land rents) and **own production factors** (e.g. family labour, own land, and equity), whether rented or owned (Eurostat, 2025a). It excludes non-factor incomes like subsidies and sources not related to production, such as tourism.

By measuring how reliably income levels are maintained despite market volatility, environmental stressors and climate-related disruptions, AFIRi provides a robust proxy for the economic resilience of EU agriculture (Sauer and Antón, 2023). Stable agricultural income supports rural development, enables long-term investment in sustainable practices, and allows farmers to adapt and innovate. The index is derived from national time series data reported by Eurostat under the Economic Accounts for Agriculture (EAA) (Eurostat, 2025b).

AFIRi highlights the importance of maintaining stable agricultural income levels to support resilience to economic and environmental challenges. High AFIRi values indicate robust economic stability, enabling farmers to invest in sustainable practices and innovations, thus ensuring long-term productivity. Low AFIRi values signal the need for policy interventions to stabilise incomes, enhance resilience, and ensure the agricultural sector's sustainability. This indicator is also relevant for monitoring progress towards the UN Sustainable Development Goals, particularly in reducing income inequality and promoting sustainable economic growth.

The methodology applied to **AFIRi** follows the same statistical workflow as described for **APri**, including detrending (Step 1; eqs. 1 and 2), stability calculation (Step 2; Equation 3), percentile classification (Step 3), and the scoring of status (Step 4; Equation 4) and progress (Step 5; eqs. 5 and 6). The only difference lies in the input variable: instead of cereal production, AFIRi is based on **real agricultural factor income**.

The supporting datasets for this sub-indicator are documented in excel file **Supplementary File 2 – AFIRi**. The first tab (*raw_data*) contains the input data extracted from Eurostat's Economic Accounts for Agriculture ([aact_eaa06](#)) on 16/12/2024. Subsequent tabs correspond to each processing step.

3.3. Water Resilience Index (WRi)

The **WRi** measures seasonal pressure on renewable water resources in agricultural regions, focusing on irrigation-driven hydrological stress. It is based on the **Water Exploitation Index Plus** (WEI+), a key CAP monitoring indicator (PMEF C.38/I.17), which expresses total water abstraction as a proportion of available renewable freshwater (Eurostat, 2025d). While WEI+ covers all economic sectors, WRi is specifically tailored to assess agricultural demand at the **monthly and regional scale**, identifying where and when irrigation places significant stress on water systems (Bisselink et al., 2020; De Roo et al., 2023).

For WRi we use calculations applying the coupled LISFLOOD-EPIC hydrological-agronomic model at 5km resolution (EEA and JRC, 2021), operated by the JRC. Future versions will use finer resolutions. LISFLOOD-EPIC, meteorological data, simulates the full water cycle from precipitation, through water use in economic sectors, to flows and stocks of water in river basins, lakes, artificial reservoirs, and groundwater. Human water abstraction and return flows from multiple sectors (irrigation, livestock, domestic use, industry and energy) are considered. Crop irrigation

requirements are dynamically simulated using the embedded crop growth components from the EPIC model and observed weather data.

Similar to WEI+, monthly WRi values range from 0 to 1. Values between 0-0.1 indicate “low water stress”, 0.1-0.2 indicate “moderate water stress”, 0.2-0.4 indicate “water stress”, and values above 0.4 indicate unsustainable “severe water stress” (EEA, 2021, 2025). WRi lower than 20% (0.2) indicates sustainable agricultural practices and resilience. Using gridded model simulations, the model highlights the temporal (monthly) and regional (watersheds within countries) changes and trends in WRi, focussing on regions where water abstraction is dominated by agriculture. The overall MS WRi resilience score in the reference and evaluation period is calculated using a river basin area and temporally weighted average exceeding WEI+>0.2, *excluding regions where agriculture is not dominating*.

The WRi is crucial for agricultural resilience to climate change, as it highlights areas and months when agriculture is facing significant water stress. High values necessitate the implementation of better water management and conservation practices to maintain agricultural productivity. Ensuring low WEI+ values supports stable agricultural outputs, reduces vulnerability to climate change, and promotes long-term sustainability in water use.

The modelled data for this sub-indicator are documented in excel file in **Supplementary File 3 - WRi_raw** data containing four datasets each in a separated tab: C - Consumption requirement for irrigation (m³/month/region); L - Locally available water (m³/month/region), calculated as precipitation minus evapotranspiration; U - Total required consumption (m³/month/region); and I - Available upstream inflow (m³/month/region). The supporting datasets containing the intermediate results are documented in excel file in **Supplementary File 4 – WRi**, with each step presented in a dedicated tab named accordingly.

Step 1 - Calculating agricultural water use dominance per river basin region

Using gridded output from the **LISFLOOD-EPIC model**, the first step is to compute the **regional agricultural water consumption ratio (R)** for each river basin and month. This ratio reflects the extent to which agriculture dominates total water use in a given region and is expressed as a **conditional ratio** that includes only basins where agricultural abstraction exceeds a predefined dominance threshold:

Equation 7. Conditional ratio of agricultural water use dominance

$$R = \frac{U}{L + I} \times \left(\frac{C}{U} > D \right)$$

Where:

U: Total required consumption (m³/month/region).

L: Locally available water (m³/month/region), calculated as precipitation minus evapotranspiration

I: Available upstream inflow (m³/month/region).

C: Consumption requirement for irrigation (m³/month/region).

D: a threshold value (0.5) indicating when agricultural water abstraction dominates total consumption in a region.

This step ensures that WRi focuses on **river basins where irrigation demand dominates**, allowing the index to isolate agricultural pressure from other sectoral uses such as domestic,

industrial, or energy abstraction. The conditional filter $\left(\frac{C}{U} > D\right)$ includes only those regions where agricultural water use exceeds 50% of total consumption.

Step 2 - Calculating the number of months exceeding Water Stress threshold

The **conditional ratio** R calculated in Step 1 identifies regions where agriculture accounts for more than 50% of total water use. Only these **agriculture-dominated regions** are retained for further analysis. For each of these regions, the monthly **Water Resilience Index** value $WRi_{m,t}$ is computed as the ratio of agricultural water demand to available renewable resources. For each river basin region and for each 15-year period p (reference and evaluation), the number of **stress months** is calculated by counting how many months exceed the defined WRi threshold:

Equation 8. Determination of stress months exceeding WRi threshold

$$Count_{m,p} = \sum_{t=1}^n WRi_{m,t} > M$$

Where:

$WRi_{m,t}$: Monthly WRi value for region mmm in month t

M=0.2: Threshold for identifying significant water stress

n=180: Number of months in each 15-year period

In all other river basin regions where **agriculture contributes less than 50%** of total water use (i.e., $\frac{C}{U} > D$, with D=0.5), the stress month count is set to zero. This ensures that the index isolates **unsustainable water use driven specifically by agriculture**, excluding regions where other sectors dominate water abstraction.

Step 3 - Calculating National Weighted WRi

For each river basin region, the ratio of exceedance occurrences is calculated by dividing the number of months where agricultural water consumption exceeds the stress threshold (Step 2) by the total number of months in the respective period. This ratio is then multiplied by the area of the corresponding region to account for its spatial extent:

Equation 9. Area-weighted exceedance ratio for regional water stress

$$RR_{m,r} = \frac{Total\ occurrences_{m,r}}{Total\ months\ in\ period} \times Area_r$$

Where:

$RR_{m,r}$ is the area-weighted exceedance ratio for Member State;

$Total\ occurrences_{m,r}$ is the number of months where $WRi_{m,t} > 0.2$;

$Total\ months\ in\ period$ is 180 for a 15-year period; and

$Area_r$ is the area of the river basin region.

To obtain the national WRi for each Member State, the sum of $RR_{m,r}$ across all relevant regions is divided by the total national area:

Equation 10. Aggregation of regional into national-level WRi

$$WRi_{m,p} = \frac{\sum_r RR_{m,r}}{\sum_r Area_r}$$

This national WRi is a dimensionless value ranging from 0 to 1, where higher values indicate more sustainable agricultural water use across space and time. A value of 1 implies that in all months and all regions, water consumption by agriculture in agriculturally dominated regions was within the sustainability limits.

Step 4 - Assigning Resilience Status and Progress

Each Member State's national WRi score is evaluated using the same percentile-based classification described in Equation 4, situating its water **resilience status** relative to other Member States. **WRi Status** reflects the frequency and extent of unsustainable agricultural water use across regions and months, capturing how consistently countries remain within sustainable limits in agriculturally dominated basins.

Progress over time is assessed by calculating the ratio between values in the evaluation and reference periods (Equation 5), and applying the same three-tier scoring logic defined in Equation 6. However, for WRi a narrower symmetric tolerance band (table 4) of $\delta = 0.01$ ($\pm 1\%$) is used. This stricter margin allows for the detection of meaningful shifts in agricultural water stress conditions that might otherwise be masked by seasonal or interannual variability.

3.4. Soil Resilience Index (SRi)

The **SRi** estimates the total organic carbon (SOC) content in agricultural topsoils (0–40 cm), a key indicator of soil health, fertility, structure, and the ability of soils to buffer environmental stressors and sustain agroecosystem services (Lugato et al., 2018). Formed through the decomposition of plant residues, SOC supports essential functions such as nutrient cycling and water retention. Its conservation also contributes to climate change mitigation by enhancing carbon storage and reducing greenhouse gas (GHG) emissions.

In addition to management practices, geographic location strongly influences SOC levels due to climatic and soil variability. Warmer, drier Mediterranean regions tend to have lower SOC than cooler, moister Northern areas, where conditions favour organic matter accumulation. Understanding these spatial variations is crucial for tailoring soil management practices to improve soil health and resilience across different regions.

These key aspects of soil functioning is captured by the PMEF indicator [C.40/I.11](#) (EC, 2025), which monitors SOC in agricultural land using periodic data from successive LUCAS topsoil surveys (2009, 2015, 2018, 2022, next year foreseen 2026) based on over 22,000 georeferenced sampling points

across the EU (ESDAC, 2022). The SRi aligns with and complements this indicator by providing a resilience-oriented analysis of modelled annual SOC trends across all Member States.

SRi is derived from the [DayCent biogeochemical model](#) (model version Gaec_v18), which simulates daily carbon and nutrient dynamics based on meteorological conditions, crop rotations, and management practices. The model is calibrated using data from the LUCAS topsoil surveys and provides annual SOC stock estimates for all EU Member States over the 2001–2021 period. Outputs are downscaled to a 100 m spatial resolution using machine learning techniques to capture variability across agro-climatic zones.

The SRi highlights the importance of maintaining high SOC levels to support agricultural resilience to climate change reflecting soils' capacity to maintain productivity and support sustainable agriculture under varying environmental conditions. High SRi values indicate robust soil health, which helps agriculture withstand climate stresses, supports sustainable crop production, and contributes to overall environmental health. Low SRi values signal the need for improved soil management practices to enhance resilience and ensure long-term agricultural productivity.

The supporting datasets for this sub-indicator are documented in excel file in **Supplementary File 5 – SRi**. The first tab (modelled_data) contains the modelled input data used, while each step presented in a dedicated tab named accordingly.

Step 1 - Calculating regional average SOC stocks and threshold exceedance

Using gridded outputs from the DayCent biogeochemical model, the first step is to compute the average SOC stock in topsoil for each NUTS 2 region over the reference and evaluation periods. We use a threshold corresponding to the 75 percentile SOC value of all EU27 NUTS2 regions above which soil is defined '**healthy**'. This value corresponds to ca. 90 Mg/ha (i.e. 90 tonnes of organic carbon per hectare). This regional threshold is informed by scientific evidence indicating that over 60% of EU soils currently fall below this value and are therefore considered 'unhealthy' (Panagos et al., 2022, 2025). Each region's Soil Resilience Score (SRi_{reg}), representing the proportion of the regional area exceeding the SOC health threshold, is then calculated as:

Equation 11. Calculated regional Soil Resilience Score

$$SRi_{reg} = \min\left(\frac{\text{average SOC}}{\vartheta}, 1\right)$$

Step 2 - Calculating national-level SRi from area-weighted regional averages

To derive national-level SRi values, the number and area of NUTS 2 regions are first identified for each Member State. For each region, the regional SRi (as computed in Step 1) is multiplied by the corresponding NUTS 2 area to obtain an area-weighted SOC score. These weighted values are then aggregated across all regions within a country. The national SRi is computed as:

Equation 12. Aggregation of regional into national-level SRi

$$SRi = \frac{\sum_{r=1}^n SRi_{reg,r} \times area_r}{\sum_{r=1}^n area_r}$$

Where:

$SRI_{reg,r}$ is the regional score for region r ,

$area_r$ is the area of region r , and

n is the total number of NUTS 2 regions within the Member State.

National SRi values are computed separately for both the reference and evaluation periods by averaging annual estimates across the respective years.

Step 3 - Assigning Resilience Status and Progress

Each Member State's national SRi score is evaluated using the same percentile-based classification described in Equation 4, situating its **Status** relative to other countries based on the distribution of **SOC levels**. This classification captures the ability of soils to maintain organic carbon stocks across diverse agro-climatic conditions, reflecting resilience in terms of long-term soil health and productivity.

Progress over time is assessed by calculating ratio between values in the evaluation and reference periods (Equation 5), and applying the three-tier scoring logic defined in Equation 6. For SRi, a symmetric tolerance band (table 4) of $\delta = 0.01$ ($\pm 1\%$) is applied to determine meaningful changes over time. The $\pm 1\%$ tolerance band (table 4) used to assess substantial SOC change over the evaluation period is motivated by the **4 per mille initiative**, which proposes an aspirational 0.4% annual increase in SOC stocks to enhance climate mitigation and food security (Minasny et al., 2017; Rumpel et al., 2018). This target has been endorsed in EU soil policy debates as a benchmark for sustainable carbon management in agricultural soils (Montanarella and Panagos, 2021; Panagos et al., 2022). Over a six-year evaluation window, this translates to a cumulative change of approximately 1.6%, justifying a $\pm 1\%$ tolerance band both realistic and policy-relevant.

3.5. Illustrative Member-State profiles of I.9

Four illustrative Member-State profiles with markedly different results demonstrate how contrasting combinations of Resilience Status and Resilience Progress manifest within the I.9 framework, reflecting each country's unique agricultural practices, climate conditions and policy choices.

Country A:

- **Status Score:** 3.5 (High resilience)
- **Progress Score:** 2.0 (Moderate progress)
- **Interpretation:** Country A has a high current resilience and moderate progress, which is a positive outcome but suggests room for further progress. The progress score of 2.0 indicates either two sub-indicators with a score of 0 (low resilience) and two indicators with a score of 1 (high resilience), or four sub-indicators each with a score of 0.5 (medium resilience).

Country B:

- Status Score: 1.5 (Low to medium resilience)
- Progress Score: 3.0 (Significant progress)

- Interpretation: Country B has a relatively low overall resilience score, but has made significant progress, caused by effective management changes in the sector, or other changes. The status score of 1.5 suggests a mix of indicators where some are below the median and others are near or above it. The progress score of 3.0 indicates significant progress in most sub-indicators.

Country C:

- Status Score: 4.0 (Highest resilience)
- Progress Score: 0.5 (Low progress)
- Interpretation: Country C has the highest current resilience, with a status score of 4.0 showing that all sub-indicators are above the EU median. The low progress suggests that C reached a plateau for one of the indicators, while the three others decreased compared to the reference period.

Country D:

- Status Score: 0.5 (Lowest resilience)
- Progress Score: 1.0 (Low progress)
- Interpretation: Country D has the lowest current resilience among EU MS, with most sub-indicators are below the median. While concerning, the progress score of 1.0 shows some progress has been made, indicating initial steps in the right direction but requiring more effort. The progress score of 1.0 can be explained by positive value of one sub-indicator, or two sub-indicators remaining the same, while all others have shown a decline.

Together, these examples demonstrate how the dual-metric structure of I.9 differentiates between current resilience capacity and its recent evolution, offering policymakers nuanced insights for tailoring interventions.

Note: The examples above are illustrative only. The composite Status and Progress scores are the unweighted sum of the four components scores (APR_i, AFIR_i, WR_i, SR_i), each taking values {0, 0.5, 1}. Therefore, composite values range from 0 to 4 in 0.5-point increments. The verbal qualifiers (“low/medium/high”, “moderate progress”, etc.) are descriptive and do not imply additional formal thresholds beyond those defined for the components.

4. The Agricultural sector resilience progress indicator (I.9) Dashboard

The Agricultural sector resilience progress indicator (I.9) Dashboard, available at https://datam.jrc.ec.europa.eu/datam/mashup/I9_RESILIENCE_INDICATOR/index.html provides insights into the Agricultural Sector Resilience Progress Indicator (I.9) through an interactive, user-friendly interface that visualises agricultural resilience across Europe. Hosted on [DataM \(Data-Modelling platform of resource economics\)](#), an online platform developed by the Joint Research Centre (JRC) for managing, visualising, and analysing EU agricultural and environmental data, the dashboard allows users to compare each country's resilience relative to the EU median during a reference period (2001–2015) and an evaluation period (2007–2021). The dashboard presents the status for the reference and evaluation periods and the improvement in relation to the evaluation period, for the composite and the individual sub-indicators.

The dashboard (Figure 1) is organized as follows: the Home tab provides an overview of the dashboard and its purpose; the I.9 Progress Dashboard displays key metrics and visualizations of resilience progress across different time periods; the Indicators Map offers a spatial representation of resilience scores by member state; the Time-series tab enables analysis of resilience trends over time; the Methodology tab details the methods and data sources used in calculating the I.9 indicator; and the Open Data tab provides access to downloadable datasets for further analysis.

Figure 1. I.9 Dashboard interface on the DataM platform. The dashboard provides an interactive environment to visualise, explore, and download data for the Agricultural Sector Resilience Progress Indicator (I.9).



Source: JRC

4.1. Home Tab

The starting page of the dashboard provides a brief overview of the I.9 indicator, outlining its purpose, scope, and relevance for monitoring resilience in the agricultural sector.

4.2. I.9 Progress Dashboard

The I.9 Progress dashboard tab provides an interactive interface for visualising the resilience of the agricultural sector in Europe. It compares each country's position relative to the EU's median for a

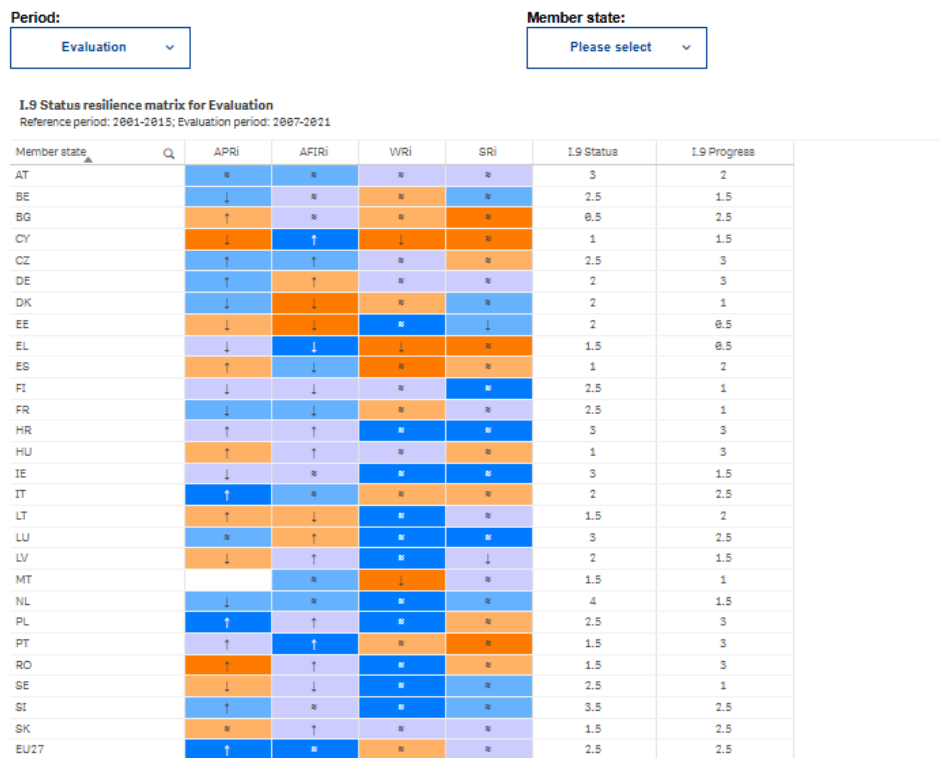
reference period (2001-2015) and an evaluation period (2007-2021), highlighting the improvement direction in relation to the country's baseline (i.e. reference period). The composite indicator, I.9, presents both the composite status for the reference and evaluation periods and the improvement in relation to the evaluation period. For a more detailed view, the dashboard also presents the four key sub-indicators: APRI, AFIRI, WRI, and SRI, which show data specific to each metric.

Users can select the desired period from a drop-down menu. When the reference period is selected, the dashboard displays only the status values, whereas selecting the evaluation period displays both status and progress values. Users can also choose which sub-indicator to view and adjust the displayed Member States. If no member state is selected, data for all member states will be displayed. The dashboard uses a color-coded system to indicate resilience groups. The highest resilient group is shown in dark blue (\geq Percentile 87.5%, Value = 1), medium-high in light blue (\geq Percentile 62.5% and $<$ Percentile 87.5%, Value = 1), medium in light purple (\geq Percentile 37.5% and $<$ Percentile 62.5%, Value = 0.5), medium-low in light orange (\geq Percentile 12.5% and $<$ Percentile 37.5%, Value = 0), and the lowest in dark orange ($<$ Percentile 12.5%, Value = 0). If no data is available, it is indicated with an empty cell.

Highest resilient group	Medium-High resilient group	Medium resilient group	Medium-Low resilient group	Lowest resilient group	No data available
\geq Percentile 87.5%	\geq Percentile 62.5% $<$ Percentile 87.5%	\geq Percentile 37.5% $<$ Percentile 62.5%	\geq Percentile 12.5% $<$ Percentile 37.5%	$<$ Percentile 12.5%	
Value = 1	Value = 1	Value = 0.5	Value = 0	Value = 0	

Arrows show the direction of change: upward arrows indicate significant improvements in resilience, downward arrows indicate significant worsening, and an equal sign indicates no substantial change. A blank cell indicates that the change cannot be calculated due to a lack of data. By "sizable change," the dashboard refers to deviations from the mean by a +/- a tolerance band (1 or 5 %) of the evaluation period relative to the reference period.

Figure 2. The I.9 progress Dashboard showing the resilience matrix for each Member State for the evaluation period (2007-2021). Please refer to the text for a further in-depth explanation of colours and symbols.



Hover the table with the mouse to see the top-right buttons for taking snapshots and downloading the data

Resilience

- Highest resilient group
- Medium-high resilient group
- Medium resilient group
- Medium-low resilient group
- Lowest resilient group
- No data

Change with regards to the Reference period

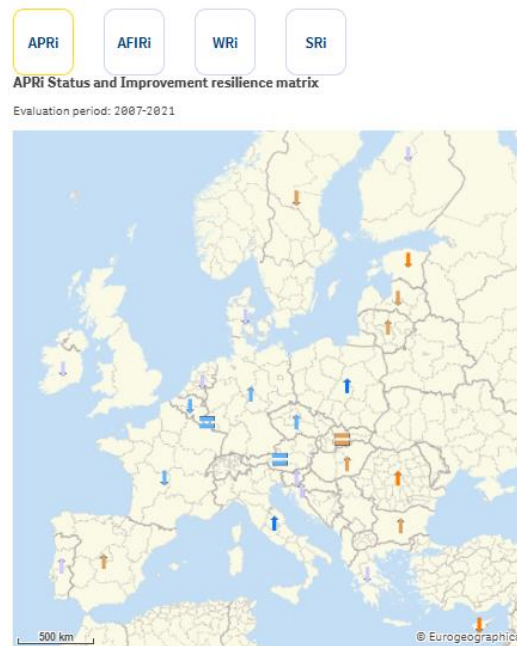
- ↑ Sizable improvement
- ≈ Not sizable
- ↓ Sizable worsening
- Plain cell shown for reference period

Source: JRC

4.3. Indicators Map

The “Indicators Map” provides a spatial representation of resilience scores across different regions or countries, allowing users to visually compare resilience levels geographically. Users can select which sub-indicator to display on the map for a comprehensive overview of resilience across different countries. Hence, quickly identify regions with varying levels of agricultural resilience and track improvements or declines.

Figure 3. Indicators Map showing the Agriculture Production Resilience Index (APRi) status and progress across EU Member States. Colours represent resilience status - from dark blue (highest resilience) to dark orange (lowest) - while arrows indicate the direction of change between the reference and evaluation periods (↑ improvement, ↓ worsening, = no change, empty cell = no data).



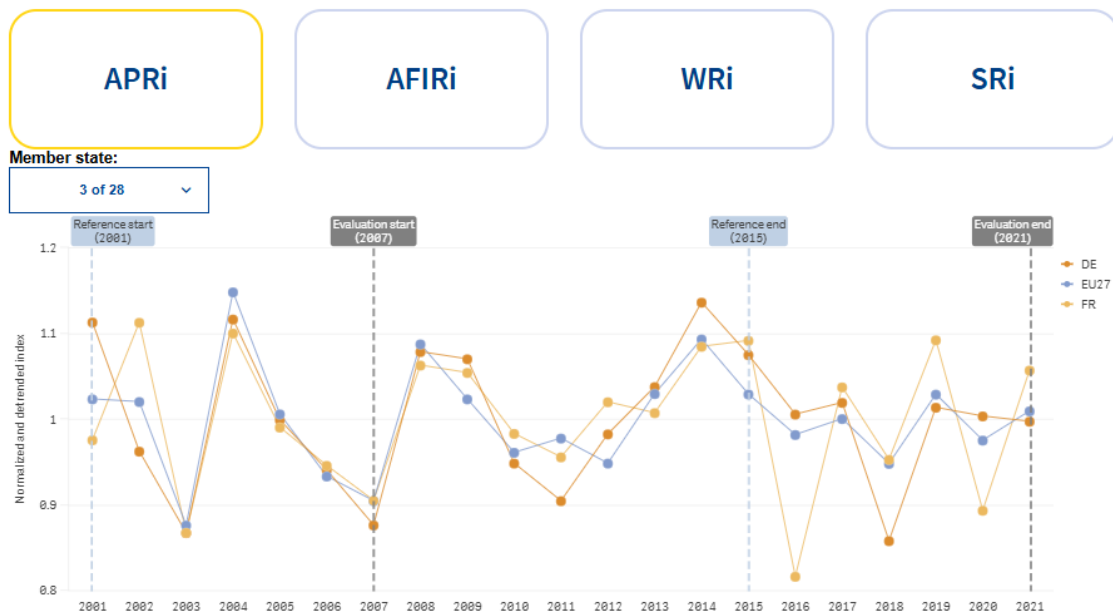
Source: JRC

4.4. Time-Series

This tab “Time-Series” offers time-series data for the I.9 indicator, enabling users to analyse trends over specific time periods. This section visualizes the time series from 2001 to 2021 for each indicator, covering Member States and the EU-27 as a whole. Users can select which sub-indicator to view and adjust the member states. Multiple countries can be selected for quick comparison, allowing users to analyse and compare the resilience trends across different regions simultaneously. The vertical lines in the timeline graph indicate key periods for data analysis and comparison:

- Reference Start (2001): Marks the beginning of the reference period, which is used as a baseline for comparing changes over time.
- Reference End (2015): Marks the end of the reference period. Data including this year are used to establish the reference period for assessing changes in the evaluation period.
- Evaluation Start (2007): Indicates the start of the evaluation period, during which the progress and improvements are evaluated against the reference period.
- Evaluation End (2021): Indicates the end of the evaluation period, providing a complete dataset for evaluating the progress and resilience improvements from 2007 to 2021.

Figure 4. Time-Series plot showing the Agriculture Production Resilience Index (APRi) raw data. EU27 is shown in blue, Germany (DE) in dark orange and France (FR) in light orange. These lines help users easily identify and differentiate between the reference and evaluation periods, allowing for a clearer analysis of trends and changes in agricultural resilience over time.



Source: JRC

4.5. Methodology

The Methodology tab provides detailed documentation on how the I.9 indicator and its sub-components are calculated. This section typically includes explanations of data sources, aggregation methods, and any statistical techniques or models used to generate the resilience scores.

4.6. Open Data

The Open Data section allows users to download raw data related to the I.9 indicator. It adheres to the European Commission's data policy, driven by transparency, with the aim of contributing to innovation. This approach is a pillar of the development and implementation of scientific knowledge management at the Commission level. It follows the commitments and regulatory basis of the [Commission Decision on the reuse of Commission documents \(2011/833/EU\)](#)

5. Statistical audit by European Commission's Competence Centre on Composite Indicators and Scoreboards (COIN)

An independent scientific audit of the I.9 Indicator was completed in June 2025 (Erhart and Schulze, 2025) by the Competence Centre on Composite Indicators and Scoreboards (COIN) of the Joint Research Centre (JRC). The audit followed COIN's ten-step protocol, analysing steps involving data generation and treatment, normalisation, weighting and aggregation, statistical coherence, and the effect of modelling choices on country results. The primary aim of the audit was to assess the conceptual validity, methodological rigour, data robustness, and policy relevance of the I.9 framework, particularly in the context of its application within the CAP PMEF. Additionally, the audit was designed to provide methodological recommendations to guide further development.

The audit commended I.9 as a pioneering and policy-relevant initiative for assessing agricultural resilience in the EU. It highlighted the strength of integrating biophysical and economic dimensions into a unified composite framework and recognised the added value of assessing both evaluation status and evaluation progress to capture static capacity and temporal change. The use of harmonised, publicly available data from Eurostat, the EEA, and JRC model outputs was considered both transparent and well aligned with policy needs. The audit also affirmed the robustness of the statistical treatment, including EU-distribution-based scoring and normalisation, and acknowledged the equal weighting scheme a reasonable choice for an exploratory index. Finally, the I.9 dashboard was praised as an effective and accessible tool for communicating results to policymakers and stakeholders.

Despite confirming the overall robustness of the framework, the COIN audit identified several areas for improvement to strengthen conceptual clarity, statistical coherence, and interpretability. The key limitations and recommendations are summarised below:

- **Address data gaps and aggregation bias.** Malta lacks APRi data for both the reference and evaluation periods, which would introduce bias if included in pillar-level aggregations. COIN therefore recommended excluding Malta from any such aggregation until APRi data becomes available and presenting only indicator-level results. Similarly, Croatia is missing AFIRi data for four years (2001–2004) within the reference period. Given the limited extent of this gap, which the developers opted not to reconstruct or estimate, COIN advised reporting Croatia's results with appropriate caution while maintaining their inclusion in the analysis.
- **Reconsider progress tolerance band asymmetry.** The use of ad hoc and heterogeneous tolerance bands ($\pm 10\%$ for APRi and AFIRi; $\pm 1\%$ for SRi and WRi) results in uneven progress value distributions across sub-indicators. COIN recommends either harmonising these tolerance bands or providing a documented justification supported by sensitivity analysis to ensure methodological transparency and comparability.
- **Re-think the ordinal scoring scheme.** The current three-grade scale ([0, 0.5, 1]) facilitates communication but compresses variance, where most Member States cluster at 0.5. COIN recommends testing continuous min–max normalisation (e.g. 0–100 scale) to enhance spread and ranking accuracy, alongside appropriate outlier treatment for heavy-tailed distributions, notably WRi. Principal Component Analysis further confirmed the multidimensionality of the two pillars: the first principal component did not meet the pre-specified criterion of explaining $>70\%$ of total variance (with eigenvalue > 1), accounting for $<50\%$ within each pillar and $\sim 55\%$ for the combined I.9.

- **Improve internal statistical coherence.** Correlation and reliability analyses revealed weak or negative associations among some Status sub-indicators (e.g. AFIRi vs. SRI, $\tau \approx -0.43$) and low internal consistency (Cronbach's $\alpha = -0.06$ for Status; 0.50 for Progress). Principal Component Analysis further confirmed the multidimensionality of the two pillars, with no single component capturing the desired explanatory threshold: the first principal component did not meet the pre-specified criterion of explaining >70% of total variance (with eigenvalue > 1), accounting for <50% within each pillar and ~55% for the combined I.9. The slight negative correlation between Status and Progress ($\tau \approx -0.05$) supports their conceptual independence. COIN therefore recommends maintaining them as separate indices and advises against aggregating into a single headline score unless future evidence justifies such integration.
- **Expand uncertainty and sensitivity analysis.** A 1,000-member Monte Carlo simulation testing alternative normalisation, aggregation, and weighting methods showed that results are most sensitive to the choice of normalisation method (2). Switching from ordinal to min–max scoring reduced rank correlation with the reference model to $\rho = 0.88$, compared to $\rho = 0.94$ when altering the aggregation method. For 58% of countries, the 95% rank intervals spanned at least five positions, highlighting the need for caution in interpreting small rank differences. COIN recommends systematically reporting uncertainty, such as rank intervals, alongside point estimates to enhance transparency and support informed policy use.
- **Harmonise scoring and visualisation scales.** The dashboard currently uses five colour classes while the underlying scoring applies a three-level scheme. COIN recommends aligning the visual and scoring scales to avoid misinterpretation, or, if this is to be maintained for communication purposes, clearly documenting the rationale and implications.

In summary, the CC-COIN audit confirmed the scientific soundness and policy relevance of the I.9 indicator, while providing constructive recommendations to guide its further development. COIN noted that several of these areas are already being addressed in the JRC's development roadmap, including updated time windows and an expanded set of indicators. It also welcomed the publication of results on the AGRI-Food Data Portal and emphasised the importance of continued open data provision to support transparency and stakeholder engagement. These improvements are foreseen for implementation in the second release of the indicator in 2026, marking a key step forward in strengthening the robustness and utility of the I.9 framework.

(²) Here, "normalisation" refers to how stability values are converted into scores. We use an ordinal scheme: each component is scored 0, 0.5, or 1 based on EU-27 percentiles. The CC-COIN audit's alternative applies min–max normalisation, scaling values to a continuous 0–1 range. This retains more variation, reduces ties, and may slightly change country rankings. Min–max is widely used in composite indicators; while more sensitive to outliers, it provides clearer relative performance and more unique ranks.

6. Conclusions and future perspectives

This technical report has detailed the methodology and rationale behind the I.9 Agricultural Sector Resilience Progress Indicator, a multidimensional framework designed to assess the capacity of EU farming systems to withstand and adapt to climate-related stressors, and reported in the CAP PMEF indicator framework Built on four components - production stability, economic viability, water availability, and soil health - I.9 distinguishes between evaluation status (a country's current capacity relative to EU peers) and evaluation progress (its temporal evolution relative to its own baseline). These two pillars are conceptually and statistically distinct, and their disaggregation is intentional. While status offers a comparative snapshot of resilience capacity, progress reflects the direction and magnitude of change, which is context-dependent and shaped by national constraints and strategies. In fact, the low Cronbach's alpha values observed in the COIN audit are not interpreted as a flaw in the framework, but rather as confirmation that Status and Progress measure distinct, non-compensatory resilience facets.

To ensure interpretability and consistency across its four sub-indicators, I.9 employs a three-grade scoring system [0, 0.5, 1] that classifies outcomes into low, medium, and high resilience. This discrete approach enhances communication with policymakers and stakeholders, emphasising broad trends and directional changes rather than precise rankings among Member States. It thus reinforces the indicator's function as a diagnostic and early-warning tool, providing a transparent framework for monitoring progress and guiding future policy discussions on agricultural resilience in the EU.

While this simplified scoring structure enhances interpretability and comparability, it also entails certain limitations. The three-grade classification inevitably reduces numerical granularity and may mask smaller differences in resilience performance between Member States. Likewise, the percentile-based ranking provides relative positioning within the EU distribution but does not quantify the actual distance from specific sustainability or resilience benchmarks. These trade-offs were accepted by design to maintain methodological transparency and policy usability across diverse agro-climatic contexts.

The release of the first operational version of the I.9 dashboard (Version: 2025/1) marks a major milestone forward in translating the framework into a practical monitoring tool. The dashboard is now publicly available via the JRC DataM platform (https://datam.jrc.ec.europa.eu/datam/mashup/I9_RESILIENCE_INDICATOR/index.html) and the Agri-food Data Portal under the CAP PMEF. It offers open access to resilience scores and their underlying datasets. Through its interactive interface, users can explore resilience dynamics across sub-indicators, Member States, and time periods. Importantly, the dashboard does not impose rigid thresholds for classifying resilience, acknowledging its multidimensional and context-specific nature.

The COIN audit confirmed the statistical soundness and policy relevance of I.9, while offering recommendations to enhance statistical treatment, scoring coherence, and the communication of uncertainty. Several of these suggestions are being incorporated into the JRC's ongoing development roadmap, with a second release of the indicator planned for 2026. However, other observations, such as the weak or negative correlations among certain sub-indicators, are actually aligned with the conceptual design of the framework. Resilience encompasses diverse, and at times, conflicting responses to stress. Trade-offs, such as stabilising yields through irrigation at the expense of increased water risk or maintaining productivity through intensive fertilisation while

degrading soil carbon, do illustrate the complex and non-synergistic dynamics that the indicator is intended to capture.

To ensure continuity in resilience assessment, we are considering a rolling 15-year moving window for the reference and evaluation periods (e.g., 2002–2016 and 2008–2022). The goal is to enable regular updates that reflect evolving environmental and socio-economic conditions across the Union. However, as noted in the JRC-COIN audit (Erhart and Schulze, 2025) overlapping windows introduce statistical dependence: with a nine year overlap, only ~40% of observations are unique, which complicates past-versus-present comparisons and can hide recent shifts. Accordingly, while this design can help keep the indicator scientifically robust and policy-relevant, we treat it as a development to be reconsidered in the next iteration, together with a documented uncertainty/sensitivity analysis.

Looking ahead, the I.9 framework will be expanded with additional resilience-related components, such as drought resilience and crop diversification, and progressively downscaled at NUTS2 level. In parallel, decomposing national results to quantify the contributions of regions and sub-sectors will reveal where strengths and vulnerabilities arise within Member States, enabling more targeted and coherent adaptation strategies. Together, these enhancements will sharpen the diagnostic power of I.9 and reinforce its value as a policy-relevant early-warning tool for a climate-resilient EU agri-food system.

7. Code availability

The dataset supporting this report includes a detailed processing pipeline implemented using R scripts (**Supplementary File 6 – Scripts.7z**). Each script is fully documented and includes an introductory section that provides an overview of the code's workflow, detailing the sequence of operations and the purpose of each step. Inline comments are embedded throughout the code to enhance clarity, offering precise explanations for key operations. This comprehensive documentation ensures the scripts are user-friendly, facilitating reproducibility and adaptation.

A README file included in the archive guides users in replicating the analysis. The file also contains the input data used in the present version of the indicator.

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List of abbreviations and definitions

Abbreviations	Definitions
AFI	Agricultural Factor Income
AFIRi	Agricultural Factor Income Resilience Index
APRi	Agricultural Production Resilience Index
CAP	Common Agricultural Policy
CC-COIN	Competence Centre on Composite Indicators and Scoreboards
DG AGRI	Directorate-General for Agriculture and Rural Development
DG CLIMA	Directorate-General for Climate Action
DG JRC	Directorate-General Joint Research Center
EAA	Economic Accounts for Agriculture
ECA	European Court of Auditors
EGD	European Green Deal
EEA	European Environmental Agency
EU	European Union
FADN	Farm Accountancy Data Network
FSDN	Farm Structural Data Network
GAEC	Good Agricultural and Environmental Conditions
I.9	Agricultural Sector Resilience Progress Indicator
LISFLOOD-EPIC	Coupled hydrological-agronomic model for water balance simulations
MS	Member States
NUTS	Nomenclature of Territorial Units for Statistics
PMEF	Performance Monitoring and Evaluation Framework

SOC	Soil Organic Carbon
SRI	Soil Resilience Index
WEI+	Water Exploitation Index Plus
WRI	Water Resilience Index

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