Measuring progress in adapting the agricultural sector to more variable and extreme weather conditions

Framework, indicator methodology and results

Technical Paper

OECD

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This technical paper is part of a substantial body of OECD work on adaptation measurement. This stream of work supports countries in measuring their progress in building resilience to changing and extreme weather conditions.

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1 Introduction

Shifting climate patterns and escalating frequency and intensity of extreme weather events threaten global agricultural production, impacting food prices and availability. Crop quality, harvest stability, as well as the spread of pests and diseases, have been influenced adversely by extreme weather events in the last decades (IPCC, 2022[1]). Altogether, global warming is estimated to have slowed down agricultural productivity by 21% since 1961 (Ortiz-Bobea, 2021[2]). Recent literature reviews suggest that extreme weather events will, globally, have negative impacts on crops (maize, wheat, rice, and soy) as well as on meat and dairy productions (Hasegawa et al., 2022[3]; Liu et al., 2024[4]; Cheng, McCarl and Fei, 2022[5]).

Although change in extreme weather conditions presents a risk for agricultural production globally, it may also create some regional opportunities. For example, the United Kingdom and Eastern Europe may experience longer growing seasons and an increase in average wheat and sugar beet (rain fed) yields from 5% to 30% by 2050 (Ciscar et al., 2018[6]). Similarly, an increase in CO_2 concentration could enhance pasture productivity in New Zealand by 20% by 2100 under a moderate greenhouse gas emission scenario, compared to scenario in which emissions will be significantly reduced, thereby benefiting both cattle and sheep production (New Zealand Ministry for Primary Industries, 2022[7]).

OECD countries have recognised the urgent need to adapt their agricultural production to the negative impact of weather variability and extreme weather events and to take advantage of potential opportunities. All OECD countries have released a National Adaptation Plan (NAP) or Strategy (NAS) - which often identifies agriculture as a key sector for adaptation – and many include adaptation[1] in their agricultural development plans. A review of National Communications submitted to the UNFCCC identified more than 600 adaptation measures and programmes implemented by 54 countries - including the 38 OECD countries - to enhance the resilience of the agricultural sector. These programmes target a wide range of adaptation measures, including adaptation planning, funding mechanisms, climate information sharing, infrastructure and technologies (e.g., irrigation and drainage) or ecosystem-based approaches (e.g. agroecology, crops diversification) (OECD, 2023[8]).

Measuring the progress of countries in adapting to more variable and extreme weather events is essential to assess the impact of implemented adaptation actions while also identifying remaining adaptation needs and policy gaps. Adaptation measurement encompasses all efforts to track progress in the implementation of adaptation actions and assess their effectiveness (OECD, 2024[9]). In the agricultural sector, this entails evaluating changes driven not only by adaptation efforts but also by external factors such as market dynamics, as well as genetic and technological progress. This process is critical for determining how effectively agricultural development strategies, particularly adaptation initiatives, are reducing current and future risks while advancing national and international adaptation objectives.

Countries face significant challenges in measuring their progress in adaptation. A recent survey shows that for OECD countries, the complexity of adaptation, the lack of available data and the difficulty in assessing adaptation effectiveness emerge as the main challenges (OECD, 2024[9]).

Indicators are an integral part of measuring progress in adaptation. As they allow to report information in a quantified, standardised and synthetised way, indicators are widely promoted as a relevant tool to track adaptation progress over time, across localities and sectors. At the 28th Conference of the Parties of the UNFCCC, countries agreed on establishing a two-year United Arab Emirates (UAE)-Belém work programme that aims to develop indicators to shed light on progress towards the seven thematic and four dimensional targets of the Paris Agreement’s Global Goal on Adaptation (GGA), including target 9b. on resilience of food and agriculture production and supply (UNFCCC, 2023[10]). Similarly, a recent OECD survey revealed that 83% of the 30 responding countries plan to use indicators to measure their progress. However, only 30% are currently implementing such indicators (OECD, 2024[9]).

This paper seeks to address challenges in measuring progress in adapting agricultural production to changing weather conditions and extreme weather events. First, the paper outlines the various dimensions through which progress in adapting the agricultural production to weather-related changes can be measured. Second, it provides OECD countries with a framework for measuring their progress in adaptation within the agricultural sector, using a set of 17 comparable and quantifiable indicators (Table 1.1). This list is meant to provide a set of actionable indicators to inform countries progress towards the thematic target 9b of the Global Goal on Adaptation of “Attaining climate-resilient food and agricultural production and supply and distribution of food, as well as increasing sustainable and regenerative production and equitable access to adequate food and nutrition for all [by 2030]” (UNFCCC, 2023[10]). These indicators could inform expert recommendations under the UAE-Belem initiative for selecting indicators to measure progress toward the Global Goal on Adaptation.

This paper builds on earlier OECD work on measuring progress in climate change adaptation (OECD, 2024[9]). The work also incorporates insights from *OECD’s 2023* Agricultural Policy Monitoring and Evaluation (OECD, 2023[8])*,* and builds on previous analyses of public policies and adaptation programmes in the agricultural sector (Ignaciuk, 2015[11]; Cobourn, 2023[12]). Additionally, this paper takes stock and expands the existing list of OECD environmental indicators, drawing from initiatives such as the Territorial Approach to Climate Action and Resilience (TACAR) and the International Programme for Action on Climate (IPAC), which monitor climate risks at national and subnational levels (OECD, 2023[13]; OECD, 2022[14]). More broadly, the *Environment at a Glance* provides indicators to describe overall progress of OECD countries across a range of environmental issues (e.g. climate mitigation, air quality or freshwater resources) (OECD, 2024[15]).

This paper focuses on the implementation of policies and measures supporting the adaptation of crop and livestock production to changing weather conditions and extreme weather events. The scope excludes aquaculture, fisheries and forestry, as well as actions related to the downstream end of the value chain (e.g. consumer behaviour, price controls, agri-food processing, trade policies) or other characteristics of the agri-food sector (e.g. farmer welfare and income, gender issues, food quality and availability, environmental or socio-economic “externalities”). A comprehensive assessment of countries’ progress towards Target 9b of the Global Goal on Adaptation would require the inclusion of these additional dimensions. In addition, this analysis focuses on tracking the implementation of measures and policies aimed at adapting agricultural production to extreme weather events thereby narrowing the scope of adaptation measurement to the efforts undertaken to foster resilience. Assessing the effectiveness and efficiency of these efforts in strengthening agricultural resilience remains an important area for future work.

The paper is structured as follows. Section 2 presents the different dimensions along which progress in adapting agricultural production to extreme weather events can be assessed. Section 3 discusses the use of indicators for measuring this progress and elaborates on the methodology used to select the indicators. Section 4 presents the selected indicators for each dimension and provides insights from the use of these indicators on progress made by OECD countries in adapting agricultural production to extreme weather events. This last section is supplemented by Annex A, which provides a detailed explanation of the rationale, data, and methodology used to develop each indicator. Annex B details country level progress along each of the suggested indicators over the last 20 years. Annex C provides additional figures.

Table 1.1. Selected indicators to measure progress in adapting agricultural production to extreme weather events

Dimension	Indicator
I: Agricultural Exposure to Extreme Weather Events	1. Cropland exposure to droughts
	2. Cropland exposure to 10-year return period flood
	3. Cropland exposure to heat stress
	4. Livestock exposure to 10-year return period flood
	5. Livestock exposure to heat stress
II: Resilient Agricultural Practices Reducing Vulnerability	6. Diversity of crop production
	7. Diversity of livestock production
	8. Crop suitability with local conditions
	9. Development of irrigation
	10. Water withdrawal for irrigation
	11. Water intensity of crop production
III: Impacts of Extreme Weather Events on Agriculture	12. Crop yield fluctuations
	13. Meat yield fluctuations
	14. Milk yield fluctuations
IV: Enabling Agricultural Adaptation	15. Innovation in agricultural adaptation technologies
	16. Planning for agriculture in NAPs, NAS or agricultural adaptation plans
	17. Adaptation policies and programmes targeting the agricultural sector

2 Measuring progress in adapting agricultural production to extreme weather events: a framework

The OECD defines adaptation measurement as “the processes, methodologies and tools for measuring the degree of implementation of adaptation policies over time and space, with the aim of evaluating the attributing effect of such efforts to the reduction in climate risks” (OECD, 2024[9]). Based on this definition, measuring progress made by countries in adapting to extreme weather events thus implies exploring the following dimensions:

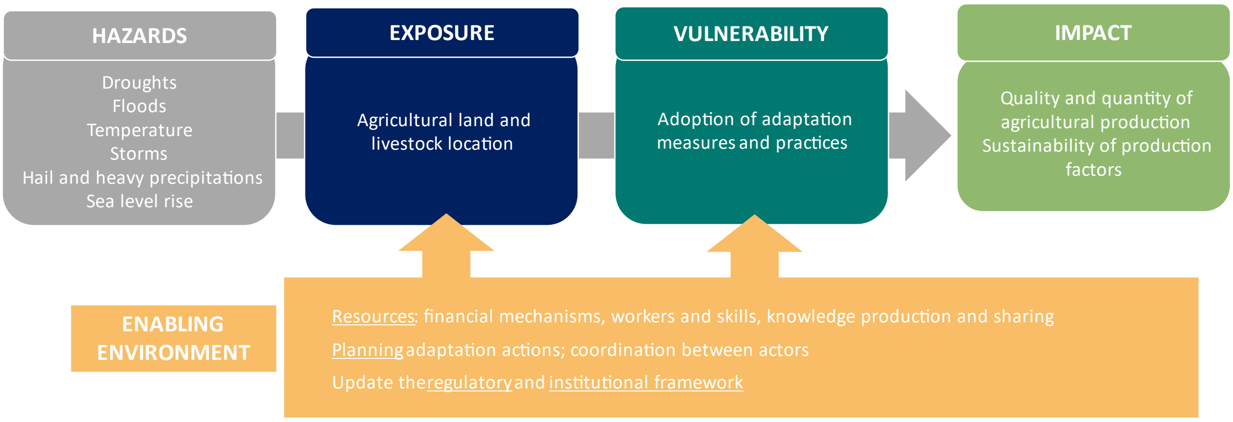
- Assessing changes to current and future risk from extreme weather events.
- Tracking resources (funding, skills, knowledge) dedicated to adaptation.
- Tracking progress made in planning for adaptation and mainstreaming adaptation into sectoral plans.
- Tracking the implementation of adaptation solutions and policies.[2]

This section aims to clarify what it means to assess progress in adapting agricultural production to extreme weather events. It begins by outlining the key components of adaptation that strengthen agriculture resilience to extreme weather events drawing on the IPCC climate risk framework. The OECD definition of adaptation measurement is then applied to these components to identify the key dimensions for effectively measuring adaptation progress.

2.1. Adapting agricultural production to extreme weather events

Adapting agricultural production aims at mitigating the negative impact of changes in weather conditions on both the quantity and quality of crop and livestock production, as well as the factors that contribute to their production. The impacts of extreme weather events (e.g., droughts, heat, floods) affect agriculture by reducing crop yields (e.g., flood damage) and harming production factors (e.g., soil erosion from heavy rainfall) (*Hazard* in Figure 2.1). For example, without adaptation, extreme weather events are projected to cause a global average reduction in maize yields of at least 25% by the end of the century (IPCC, 2022[1]). Beyond these immediate impacts, changing weather conditions and extreme weather events also affect the long-term sustainability of production, such as soil health, water quality and livestock fertility (IPCC, 2022[1]).

Figure 2.1. Adapting the agricultural production to extreme weather events: a framework



Source: Authors.

Adapting agriculture to extreme weather events may require a change in the location of the production. Impact of extreme weather events is first a function of the exposure of agricultural production to these hazards, that has increased since the beginning of the 21st century (OECD, 2024[16]). Almost 80% of global cattle production is exposed to weather conditions leading to heat stress at least a month per year (North et al., 2023[17]). The average area of cropland in OECD countries exposed to more than one week of extreme precipitation has increased fivefold between the periods 2000-2005 and 2018-2023. Over the same period, the average soil moisture of cultivated land in OECD countries has halved (OECD, 2024[16]). For example, relocating farming to the most suitable regions could drastically reduce the need for irrigation (Beyer et al., 2022[18]).

In addition to managing production locations, implementing adaptive agricultural measures and practices on the ground can reduce vulnerability and help mitigate the impacts of more variable weather and extreme weather events. The IPCC defines vulnerability as “the propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt” (IPCC, 2022[1]). Vulnerability is a complex concept influenced by various factors, such as farmers' income, capital, age, education, and gender, as well as the adoption of adaptive measures and behaviours. Change in agricultural practices and species grown or bred as well as the adoption and upgrade of technology and infrastructures can be adopted at various scales to foster the resilience of the agricultural production (see Table 2.1 below for an overview). For example, estimates suggest that change in crop calendar may increase global yields by 12% compared to a situation with no adaptation at the end of the century (RCP 6.0 scenario) (Minoli et al., 2022[19]). Similarly, switching crops could cut future impacts of extreme weather events on US crop yields by half (Rising and Devineni, 2020[20]). Finally, the development of irrigation may decrease the impact of extreme weather events on global crop yields by 12% by 2100 (IPCC, 2022[1]).

Table 2.1. Actions to adapt the agricultural production to more variable and extreme weather events

Category	Adaptation actions
Production relocation	Changes in cultivation and breeding locations
Change in agricultural practices	Adjustment in farming calendar (e.g. adjusting planting or harvesting dates) Changes to the formulation of livestock feed Invasive species inspection programmes and measures Practices to combat soil erosion and preserve soil health (e.g. conservation tillage, manure management)
Change in species/products	Develop or select adapted breeds and cultivars Adjust choice of species to changing growing conditions (e.g. heat or drought tolerant species) Diversify crops and livestock production
Infrastructure & technology (upgrade and implementation)	Irrigation and drainage infrastructure Water storage and supply systems Cooling, ventilation and design for greenhouses and livestock buildings Protective infrastructure (e.g. dykes, dams, mangroves) Early warning systems Climate smart agriculture technologies
Knowledge and innovation	Development of climate risk assessment tools Tools and platforms to collect and disseminate information (e.g. forecasted climate scenarios, best adaptation practices) Training for farmers Mainstreaming adaptation into farmers' education Research programmes (e.g. technology development, assessment of solutions' effectiveness)
Financing	Funding for adaptation (e.g. support for the development of resilient practices, payments for environmental services) Creating or expanding insurance mechanisms (e.g. recovery funding)
Planning and coordination	Developing adaptation strategies or plans for the agricultural sector Creation of coordination body for action in adaptation
Regulatory and institutional environment	Economic based instruments (e.g. taxes, subsidies) Legislative changes, including the creation or amendment of laws Creation of entities responsible for action Review mandate of existing institutions and various stakeholders

Source: Authors' own, adapted from the OECD Agricultural Policy Monitoring and Evaluation 2023 (OECD, 2023[8]).

Government's intervention is necessary to create an environment that supports adaptation and encourages changes in exposure, as well as the adoption of adaptive measures and practices to reduce vulnerability. While farmers may act autonomously to changes in local conditions to reap the private benefits of adaptation action, it is unlikely that autonomous adaptation will lead to a sufficient or socially optimal level of resilience of the agricultural sector (IPCC, 2022[1]). Lack of information, of technical and financial capacities and of economic incentives, as well as inappropriate institutional and regulatory framework may undermine actions for adaptation or even lead to maladaptation (OECD, 2023[8]). In addition to addressing these barriers, public policy also plays a key role in correcting for externalities created by individual actions, in providing infrastructure and ensuring coordinated actions. Given the local specificity of actions needed on the ground, efforts of policymakers should focus on enabling the agricultural sector to adapt, rather than to target specific adaptation strategies or actions (OECD, 2023[8]).

Creating an enabling environment for adaptation requires the allocation of resources, such as funding mechanisms, skilled workers and the production and sharing of knowledge. The lack of information and funding are key barriers to the adoption of adaptation measures and practices (Wreford, Ignaciuk and Gruère, 2017[21]). In addition, adapting to extreme weather events may require the development of new technologies and innovative agricultural approaches. To overcome these obstacles, many OECD countries have set specific programmes and dedicated funding to build adaptation capacity in the agricultural sector, in particular to increase knowledge regarding future climate risks and develop new adaptation solutions (OECD, 2023[8]). In its Third National Adaptation Programme (NAP3), the United

Kingdom committed to spend GBP 30 million to research aimed at improving livestock resilience to climate change (DEFRA, 2023[22]). The Australian platform “My Climate View”, as well as the French DRIAS portal both provide farmers with information on current and projected local conditions and different hazards (e.g. drought and floods) (CSIRO and Bureau of Meteorology, 2024[23]; Ministère de la Transition Écologique and Météo France, 2022[24]). The Austrian Agency for Health and Food Safety (AGES) provides the AgriWeedClim database, a tool designed to assist farmers in identifying and managing emerging invasive weed species (AGES, 2023[25]).

In addition to allocating resources for adaptation, public authorities also play a key role in planning and coordinating adaptation action. Given the long-term and multi-dimensional nature of the adaptation process - requiring collaboration among multiple stakeholders across various localities which (OECD, 2023[26]) - planning for adaptation at different geographical and temporal scales is crucial. This is particularly important in the agricultural sector, where reliance on shared natural resources demands careful management to ensure their sustainable use. Furthermore, since adaptation involves the allocation of limited resources, many countries established priorities and strategically planned the measures to be implemented. For example, Austria details a specific objective, role and responsibilities of different stakeholders, a time horizon and potential conflicts with other sectors for each of the 12 recommendations for action in agricultural sector (BMK, 2024[27]).

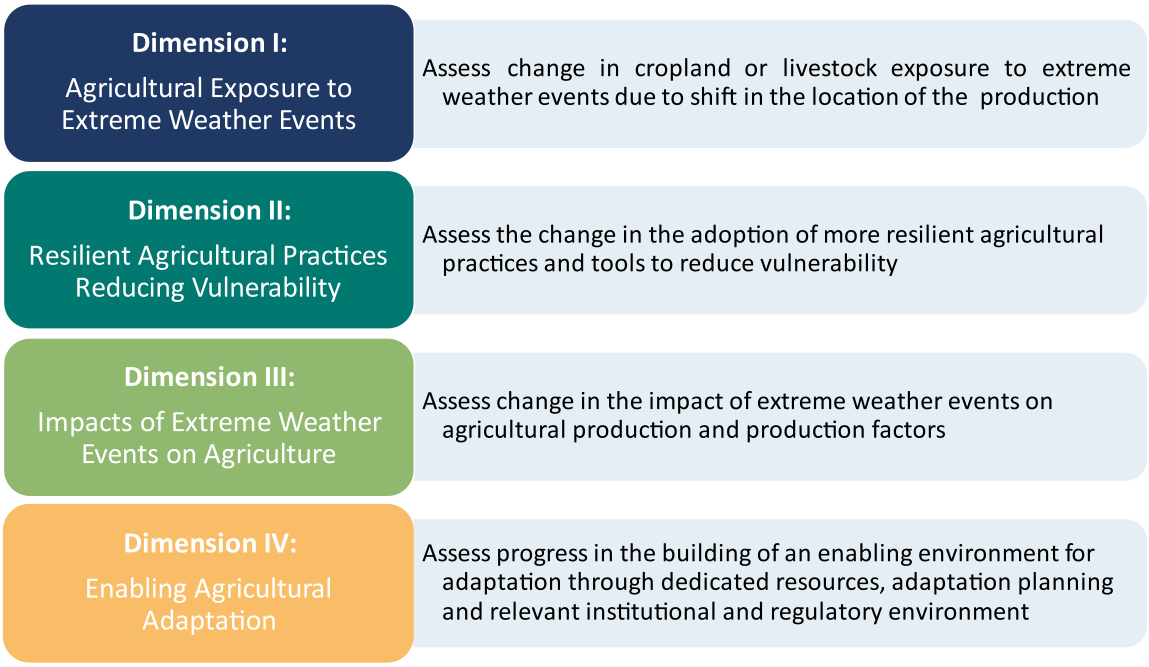
Setting an enabling environment also requires updating the institutional and regulatory framework to ensure it does not obstruct adaptation actions and actively incentivizes their adoption. While farmers' decisions are driven by economic interests and personal beliefs, their actions are also shaped by the regulatory framework (Ignaciuk, 2015[11]; OECD, 2023[8]). It may therefore be necessary to modify this environment to ensure it supports (or even mandates) adaptation actions and remains responsive to changes in impacts and adaptation needs. For example, in 2023, France revised its crop insurance scheme to offer better coverage for risks associated with extreme weather events, while also encouraging farmers to increase their insurance coverage for crops (Ministère de l'agriculture, de la souveraineté alimentaire et de la forêt, 2023[28]). In Israel, the Water Authority sets annual water quotas for each farm and uses tiered pricing to discourage overuse and prevent water shortages during droughts (OECD, 2023[29]).

2.2. A four-dimensions framework to measure progress in adapting the agricultural sector

Measuring progress in adapting agricultural production to more variable and extreme weather conditions thus encompasses the following four dimensions (see Figure 2.2 below):

i. Assessing change in exposure of the agricultural production due to change in crops and livestock location.
ii. Assessing progress in the implementation of agricultural measures and practices to reduce vulnerability.
iii. Assessing change in the impact of extreme weather events on agricultural production and production factor (e.g. soil fertility, water quality).
iv. Assessing progress in building an enabling environment for adaptation through dedicated resources, planning and coordination, and update of the regulatory and institutional environment.

Figure 2.2. Four dimensions to measure progress in the adaptation of the agricultural production



Dimension I: Agricultural Exposure to Extreme Weather Events	Assess change in cropland or livestock exposure to extreme weather events due to shift in the location of the production
Dimension II: Resilient Agricultural Practices Reducing Vulnerability	Assess the change in the adoption of more resilient agricultural practices and tools to reduce vulnerability
Dimension III: Impacts of Extreme Weather Events on Agriculture	Assess change in the impact of extreme weather events on agricultural production and production factors
Dimension IV: Enabling Agricultural Adaptation	Assess progress in the building of an enabling environment for adaptation through dedicated resources, adaptation planning and relevant institutional and regulatory environment

Source: Authors' own.

Measuring progress in weather-proofing agricultural production first involves analysing changes in exposure to extreme weather events due to shifts in production locations. The exposure is influenced by two factors: the location of the production and local weather conditions. While limiting the worsening of extreme weather events necessitates mitigation efforts, progress in adaptation is highlighted by the development of agricultural production towards safer or more favourable areas. This assessment requires the identification of current and future hazard-prone (or more favourable) areas and the evaluation of how the production has been distributed across these areas over time.

Tracking adaptation efforts also involves monitoring the adoption of climate-resilient agricultural practices to reduce the sector's vulnerability to changing weather conditions. This paper focuses on the adoption of agricultural tools and practices aimed at reducing vulnerability, as they provide evidence of adaptation efforts implemented on the ground. Although, while other generic factors, such as farmers' income and age, significantly impact vulnerability, they do not serve as direct measure of the level of preparedness to cope with extreme weather events. Thus, change in agricultural practices and adoption of adaptation solutions are often targeted by countries as adaptation objectives in their NAP or NAS. For example, Austria promotes the development of more efficient irrigation systems, climate-resilient crops and organic farming as three key actions for the agricultural sector in its National Adaptation Strategy (BMK, 2024[27]). When changes in agricultural practices are difficult to track due to the granularity and specificity of farm-level data required, their direct impacts on broader characteristics of the agricultural sector, often aggregated at regional or national levels, can serve as more easily observable proxies for the adoption of these practices. For example, Spain monitors the development of more efficient irrigation systems by tracking the volume of water used for irrigation (Gobierno de España, 2020[30]).

Monitoring the evolution of the quantity and quality of agricultural production and its production factors gives insights on overall resilience of the sector to extreme weather events. As impacts of extreme weather events result from shifts in exposure to hazards and the adoption of adaptation measures, monitoring changes in the production provides insights into the agricultural sector's evolving resilience. By accounting for changes in the occurrence and intensity of extreme weather events, monitoring their impacts can also shed light on the effectiveness of adaptation efforts in building more resilient agricultural systems. However, this aspect is outside the scope of this analysis.

Measuring countries' progress in adapting agricultural production to extreme weather events also involves tracking the establishment of an enabling environment for adaptation. Although tracking progress in resource allocation, the planning of adaptation, or the update of institutional and regulatory frameworks does not directly measure the resilience of agricultural production, it helps governments monitor progress toward specific adaptation goals. Many countries' adaptation objectives focus on creating an environment that supports the adoption of resilient behaviours and practices (Ignaciuk, 2015[11]; Cobourn, 2023[12]). Furthermore, tracking the implementation of actions to build this enabling environment is an essential first step in evaluating the effectiveness of government efforts to strengthen the resilience of the agricultural sector.

3 Indicators to measure progress in adapting agricultural production to extreme weather events

This section discusses the extent to which indicators can be used to review progress in adaptation. It briefly reviews the rationale for and current barriers to using indicators to measure progress, before presenting the methodology and criteria used to select indicators for monitoring the adaptation of agricultural production along the four dimensions of the framework described above.

3.1. Using indicators to measure adaptation progress: Rationale and challenges

Indicators simplify, quantify, and standardise information, facilitating the assessment and communication of progress in adaptation. While countries use a variety of tools to analyse and report their progress (e.g. expert committees, surveys, and public or targeted consultations), indicators offer several comparative advantages. Indicators are used to report qualitative and quantitative information (OECD, 2024[9]). They serve both as a framework and a tool for reporting progress on adaptation. Using indicators provides a framework as they guide, co-ordinate and encourage the consistent collection of information across time, locations, stakeholders, and sectors. Guidelines on the computation of the indicators also improve the standardisation of the collected information, particularly when they rely on qualitative assessment. Indicators can also improve the understanding of a specific adaptation objective, as well as increase the transparency of actions taken and progress made. This increased concreteness and accountability thus encourage and shape adaptation efforts. Characteristics of indicators also make them an appropriate tool to measure progress on adaptation. The standardisation of indicators makes it possible to track and quantify progress over time in a coherent manner, and to identify areas where additional adaptation efforts are needed. The homogeneity of collected data allows aggregation across various locations, timeframes, and sectors, facilitating comparisons among stakeholders or regions. Finally, although this dimension is not addressed in the present analysis, the standardisation of information provided by indicators can also facilitate quantitative and statistical assessments of the impact, effectiveness, and efficiency of various measures.

Many international initiatives highlight the relevance of indicators and promote their development to monitor progress in adaptation, including in the agricultural sector. Numerous international initiatives seek to develop indicators for measuring progress on adaptation. The UAE-Belém two-year work programme aims to develop a set of indicators to measure progress across the seven thematic targets of the Paris Agreement's Global Goal on Adaptation, one of which focuses on "climate-resilient food and agricultural production". Submissions of parties and observers to the UNFCCC have gathered more than 1,800 indicators related to this target "9b. Food & agriculture production and supply" (UNFCCC, 2024[31]). Similarly, the global indicator framework for Sustainable Development Goals (SDGs) provides a list of official indicators to measure progress against the different targets of the 2030 Agenda for Sustainable Development (United Nations, 2024[32]). Among these is indicator 2.4.1, 'Proportion of agricultural area under productive and sustainable agriculture,' which measures overall advancements in building resilience in the agricultural sector.

Most OECD countries support the use of indicators as an effective tool for measuring and communicating progress in adapting to extreme weather events. 80% of the 30 countries responding to the OECD survey on adaptation measurement emphasise their interest in using indicators (OECD, 2022[33]). Countries make use of indicators to assess their risk. For example, Chile developed a climate risk platform using 45 indicators to assess climate risk, including in the agricultural sector (Ministerio de Medio Ambiente, 2020[34]). Indicators are also used to identify adaptation trends and monitor progress towards adaptation objectives in the agricultural sector. For example, Germany used 10 quantitative indicators to report progress on adaptation in the agricultural sector in its 2023 Monitoring Report on the German Strategy for Adaptation to Climate Change (Interministerial Working Group on Adaptation to Climate Change, 2023[35]). The United Kingdom identified 600 indicators to track progress across 13 sectors, including agriculture (OECD, 2024[9]), while Austria evaluates adaptation efforts through a stakeholder-driven process using both qualitative and quantitative indicators (BMK, 2020[36]).

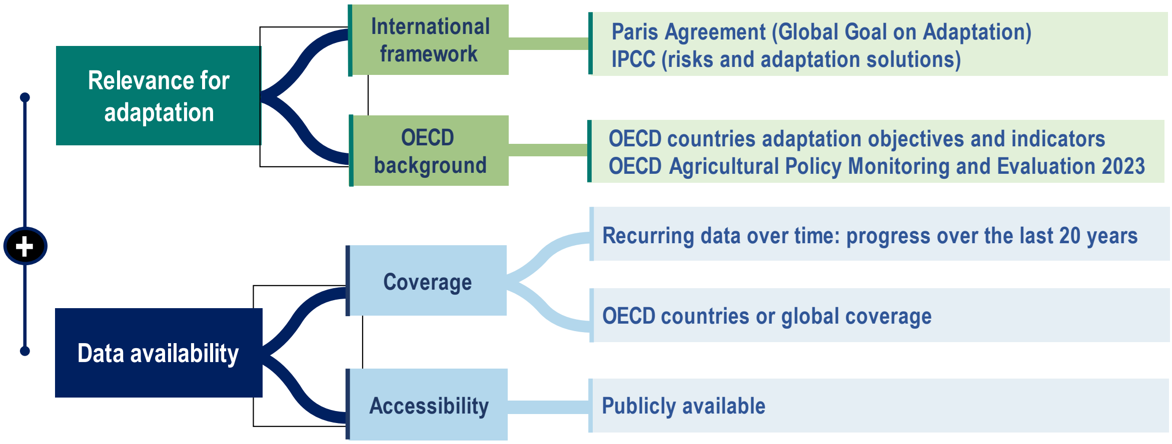
Information gaps and the complexity of adaptation are the main challenges to the effective use of indicators. As of 2023, only 30% of the countries responding to the survey had implemented indicators to measure their adaptation progress (OECD, 2024[9]). Similarly, 60% of the adaptation indicators identified by the United Kingdom constitute a wish-list, namely indicators that appear as relevant to measure progress in adaptation but for which the country lacks data and information (OECD, 2024[9]). Unlike greenhouse gases emissions for mitigation, there is no common metric to assess progress in adaptation due to the diversity and context-specificity of adaptation goals and solutions. The absence of clear adaptation objectives, combined with the difficulty of attributing changes in weather impacts directly to adaptation efforts, further complicates the assessment of progress toward resilience. In addition, because the effectiveness and benefits of many adaptation actions are highly regional and context-specific determining whether a given intervention will enhance resilience or inadvertently lead to maladaptation (e.g. by increasing long-term vulnerability or displacing risks to other regions, sectors, or populations) is challenging. Consequently, defining what should be measured to assess progress and establishing clear criteria for success in adaptation remain key challenges for most OECD countries. In addition, lack of comparable data over time, technical barriers to its collection and use, as well as the diversity of information reported from different stakeholders make national level assessment of adaptation progress an issue (OECD, 2024[9]).

3.2. Adaptation indicators: selection criteria and methodology

3.2.1. Selection criteria

The selection of indicators to inform adaptation progress across the four dimensions is guided by a set of criteria and a methodology specifically designed to address the challenges faced by OECD countries in assessing their progress in adaptation. This work aims not only to provide OECD countries with a common set of indicators but also to provide information regarding their progress in adapting the agricultural sector to changing weather conditions. The selection goes beyond a simple wish list of relevant indicators, and also identifies the necessary data and proposes a methodology for calculating them. To do so, the selection of computable and relevant indicators is grounded in two key criteria: data availability and the relevance to adaptation in the agricultural sector (Figure 3.1).

Figure 3.1. Criteria for the selection of indicators



Source: Authors' own.

Relevance for adaptation

The selected indicators aim to reflect adaptation efforts specific to the agricultural sector and to align with the adaptation needs and priorities of OECD countries in this sector. Relevance of indicators for adaptation and their specificity to the agricultural sector is checked against up-to-date academic literature -including main risks of extreme weather events and adaptation solutions reported in the last IPCC AR6 report (IPCC, 2022[1]) - and existing OECD work reporting adaptation solutions to increase the resilience of the agricultural sector (Ignaciuk, 2015[11]; OECD, 2023[8]). OECD countries' adaptation needs and priorities highlighted in their official communication and planning documents (e.g. NAPs, NAS, NDCs or adaptation progress assessment) are also used to ensure the relevance of the selected indicators for OECD countries. The selected indicators focus on adaptation efforts specific to the agricultural sector. Indicators targeting general adaptation efforts (e.g. funding to conduct risk assessment or existence of a National Adaptation Plan) are not included.

This work aims to inform and reflect latest efforts by OECD countries and the international community in developing indicators. To ensure the indicators are aligned with international and OECD standards and criteria, the selection is based on an in-depth review of existing indicators reported by OECD countries and international initiatives, such as the global indicator framework for Sustainable Development Goals SDGs or the collection of indicators under the UAE-Belém framework. The indicators adopted in this analysis align with the Global Goal on Adaptation target on 'Climate resilient food and agricultural production'. They also meet key criteria for the selection of indicators under the UAE-Belém framework (Box 3.1), ensuring their relevance and effectiveness in supporting global efforts to define indicators for measuring adaptation progress.

Box 3.1. Suggested criteria to select indicators under the UAE-Belém framework

At the June 2024 SB60 meeting hold in Bonn, the two UN Climate Change subsidiary bodies (the Subsidiary Body for Scientific and Technological Advice (SBSTA) and the Subsidiary Body for Implementation (SBI), advising and assisting in the implementation of the Paris Agreement, agreed on a list of 12 criteria for the selection of indicators to measure progress toward the Global Goal on Adaptation (see Table 3.1 below). These criteria were further complemented by 5 criteria at COP 29/SB61.

Table 3.1. Criteria for the selection of indicators to measure progress against the GGA and their inclusion in the present analysis

	Criteria
SBSTA and SBI criteria (Bonn June 2024)	Relevance of the indicators to measuring progress towards one or more of the GGA targets
	Relevance of the indicators to adaptation, including enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change;
	Quantitative and/or qualitative information applies to the indicators;
	Data availability for the indicators;
	Ability of the indicators to reflect regional, national and local circumstances;
	Applicability of the indicators across different contexts;
	Ease of interpretation of the indicators;
	Clarity of methodologies associated with the indicators;
	Ability of the indicators to be aggregated across levels and disaggregated by demographic and socioeconomic characteristics, such as vulnerability, gender, age, disability, race, socioeconomic status, and status as Indigenous Peoples, as appropriate and depending on national circumstances;
	Indicators' basis on the best available science;
	Indicators' basis on traditional knowledge, Indigenous Peoples' knowledge and local knowledge systems;
	Indicators should not be used as a basis for comparison between Parties.
Additional criteria (COP29)	Measurability and availability of data enabling the transparent monitoring of progress
	Ability to use data that are already available or can be easily collected by countries, including data from international databases and standardized reporting practices
	Use of metrics where baselines exist
	The relevance to multiple thematic targets
	Outcome and output orientation

Note: Criteria fulfilled by the methodology and selection criteria suggested in this analysis are in green. Criteria in grey are not included as selection criteria in this analysis.
Source: FCCC/SBSTA/2024/7, paragraph 41 (UNFCCC, 2024[37]), and 3/CMA.6, paragraph 17 (UNFCCC, 2024[31]).

Data availability

To favour ease of use and replicability, the indicators are developed using only publicly available data covering at least all OECD countries. The use of publicly available data ensures all OECD countries and external experts can make use of the suggested indicators without dedicating efforts to collect and standardise data. In practice, most of these datasets have a global coverage and can also be used to assess progress of non-OECD countries. In addition, the indicators are designed to be as simple as possible to facilitate their use by both countries and non-governmental experts. While they may involve implementing a formula or mapping gridded data, they are based on straightforward combinations of datasets and do not require complex statistical analysis.

Measuring progress of countries over time also requires the use of recurring data. This work seeks to assess, to the extent possible, the progress made by OECD countries during the period from 2000 to 2020. This period is long enough to highlight actions taken by countries and their outcomes, and recent enough to coincide with countries' growing awareness of the need to adapt. This recent timeframe also coincides with a substantial increase in data availability. Moreover, monitoring progress over a 20-year period allows for the identification of adaptation trends and helps to overcome short-term fluctuations caused by weather conditions, pest and disease, market shocks or agricultural practices (e.g., crop rotation).

3.2.2. Step-by-step indicator selection and building

In practice, the selection and building of indicators followed the following steps:

i. **Defining what should be measured:** Review of the OECD work and academic literature to identify main adaptation solutions (including on-field measures, national and subnational policies, programmes and initiatives) as well as main types of extreme weather events and their impact on agricultural production.

ii. **Reviewing existing indicators:** Review of existing indicators suggested or used by international organisations, NGOs, OECD countries and academic analysis to measure progress on adaptation in the agriculture sector.

iii. **Establishing a preliminary list of indicators:** A “wish list” of indicators was compiled from the different sources identified in the previous stage, based on their consistency with the adaptation objectives and programmes of OECD countries highlighted in theirs NAPs/NAS, their specificity for adaptation in the agricultural sector and their compatibility with one of the four dimensions of the framework. Suggestions from OECD experts further enriched this list.

iv. **Collecting available data and information:** The initial list of indicators was refined according to the data available (see criteria in the previous section).

v. **Building the indicators:** The design of the indicators, including formula and thresholds, was improved in light of the academic literature and OECD expertise to enhance their accuracy and relevance.

vi. **Computing the indicators:** The selected indicators were computed using available data to provide insights into the progress of OECD countries across each of the four dimensions of adaptation over the last 20 years.

3.2.3. Limitations of the approach

The proposed methodology provides a standardised and transparent approach for selecting indicators to track agricultural adaptation progress in OECD countries. It provides OECD countries with a common list of usable indicators, based on the most recent literature and aligned with their adaptation objectives. While this methodology marks a significant improvement in countries' ability to assess their adaptation progress, it also comes with several limitations:

- The use of publicly available data ensures that the indicators are accessible to a broad audience, fostering transparency and widespread use. However, this approach also constrains the accuracy and comprehensiveness of the indicators, as the scope and granularity of publicly accessible data are often limited (Table A C.1 presents examples of indicators excluded from this analysis due to data limitations). Notably, there is a significant gap in tracking progress related to policy implementation due to a lack of detailed information, which impedes a full understanding of countries’ efforts to create an enabling environment for adaptation. More broadly, although the coverage and accuracy of many data sources, particularly those based on remote sensing, have steadily improved, they remain subject to measurement uncertainties. Additionally, national-level indicators fail to capture the heterogeneity in regional adaptation progress and gaps. Countries can address these issues by using other sources of national or subnational data.

- Essential to ensure the conciseness of the list of indicators, the focus on agricultural production offers an incomplete assessment of the sector's resilience to extreme weather events and partially informs progress towards Target 9b of the Global Goal on Adaptation on the resilience of the food and agricultural sector. By excluding upstream activities (e.g. input supply), downstream processes (e.g. transportation or food processing), but also the impact of extreme weather events and policies on environmental and socio-economic factors (e.g. farmers livelihoods, consumers behaviours and biodiversity), the analysis cannot provide a comprehensive view on all factors contributing to the resilience of the sector.
- A key limitation of this approach is its inability to attribute observed trends to specific drivers. Observed trends conflate impacts of extreme weather events, adaptation efforts, and external drivers like market shifts, broader agricultural development objectives or technological innovation. This ambiguity prevents the assessment of adaptation policies' effectiveness and of country's adaptation efforts as a whole.
- These indicators provide valuable information on the direction of change but do not assess successes, failures, or remaining gaps in adaptation. In the absence of common adaptation objectives, the analysis cannot evaluate progress toward specific goals. Additionally, the implications of certain adaptation strategies can be contentious and require countries to contextualize trends against national priorities. For example, while irrigation can reduce yield losses during droughts, it may also exacerbate water scarcity, potentially leading to maladaptation.

4 Progress of OECD countries in adapting agricultural production to extreme weather events

The suggested indicators encompass many of the adaptation solutions and programmes promoted by OECD countries. Specifically, the indicators presented in Table 1.1. cover 7 out of the 16 categories of adaptation solutions identified in the OECD 2023 Agricultural Policy Monitoring and Evaluation report, accounting for approximately 60% of all adaptation programmes reported by OECD countries in their National Communications to the UNFCCC (OECD, 2023[8]). Moreover, these indicators address each of the four dimensions of the measurement framework outlined in Section 2.

The following section describes the 17 indicators selected and details some of the insights provided by these indicators on progress made by OECD countries in adapting their agricultural production to extreme weather events. These indicators are designed to measure progress within countries and conducting cross-country comparison is out of the scope of this analysis, due to differing risks faced by countries and their distinct adaptation priorities. Additional details on the indicators' development are provided in Annex A. Annex B details country score for each of the selected indicators and Annex C provides additional figures to further refine the analysis.

4.1. Dimension I: Agricultural Exposure to Extreme Weather Events

4.1.1. Description of indicators

The selected indicators track changes in the exposure of agricultural production to heat, drought, and flood risks resulting from shifts in crop or livestock location during the period 2000–2020 (Table 4.1). Unlike traditional exposure metrics, these indicators aim to distinguish changes in exposure due to shifts in weather conditions and extreme weather events from those driven by changes in production location, providing insights into adaptation behaviours. The work focuses on heat stress, drought and floods, as they are identified by OECD countries as key threats to crops and livestock production (Cobourn, 2023[12]). Other hazards - such as storms, hail or sea-level rise - are not included in the analysis due to data limitations and insufficient information on their specific impacts on agricultural production, which hinders the identification of risk-prone areas for these hazards.

Table 4.1. Indicators for dimension I: Agricultural Exposure to Extreme Weather Events

Domain	Indicator	Description	Data
Cropland	Cropland exposure to drought	Percentage of total country's cropland area located in drought prone areas, identified as areas where the number of days with soil moisture below 200kg/m3 increased by four or more days during the growing season between the reference period* and 2015-2020, threshold corresponding to a 1% decrease in crops yields.	• Copernicus Global Land Cover (Copernicus Climate Change Service, 2019[38]) • Copernicus Climate Change Service (C3S) (Copernicus Climate Change Service, 2018[39])
	Cropland exposure to 10-year return period flood	Percentage of total country's cropland area located in flood prone zones, defined as regions exposed to 10-year return period floods during the period 1979–2013.	• Copernicus Global Land Cover (Copernicus Climate Change Service, 2019[38]) • Global river flood hazard maps (Baugh et al., 2024[40])
	Cropland exposure to heat stress	Percentage of total country's cropland area exposed to increasing heat stress, defined as areas where average number of hours spent above 30°C per year during the growing seasons increased by at least 44 hours between the reference period* and 2015-2020.	• Copernicus Global Land Cover (Copernicus Climate Change Service, 2019[38]) • ERA5-Land hourly data (Muñoz Sabater, J., 2019[41])
Livestock	Livestock exposure to 10-year return period flood	Percentage of total country's Livestock unit located in flood prone zones, defined as regions exposed to 10-year return period floods during the period 1979–2013.	• Gridded Livestock of the World (GLW-4) (Gilbert et al., 2018[42]) • Global river flood hazard maps (Baugh et al., 2024[40]).
	Livestock exposure to heat stress	Percentage of country's livestock units exposed to increasing heat stress, defined as areas where the annual number of days with an average daily Temperature and Humidity Index (THI) greater than 69 has increased between the reference period* and 2015-2020.	• Gridded Livestock of the World (GLW v4) (Gilbert et al., 2018[42]) • ERA5-Land post-processed daily statistics (Copernicus Climate Change Service, 2024[43])

Note: *The reference period is 1980-2010.

Developing exposure indicators first requires identifying areas at risk of drought, flood and heat stress. Historical gridded meteorological data, similar to those used in other OECD initiatives on exposure indicators are utilized to analyse past weather conditions (OECD, 2023[13]; OECD, 2022[14]). These indicators define areas at risk based on deviation of recent average local environmental conditions from historical ones, thus controlling for long-term local climate specifies. Drought prone areas are identified as areas where the number of days with soil moisture below 200kg/m^3 increased by four or more days between the reference period and 2015-2020. This threshold corresponds to a 1% average decrease in crops yields (Ortiz-Bobea et al., 2019[44]). Flood-prone areas are defined as regions where the estimated depth of 10-year return period floods during the period 1979–2013 exceeds zero. Heat-stress areas for cropland are determined as regions where the number of hours above 30°C during the growing season increased by more than 44 hours between the reference period and 2015–2020, a threshold associated with an average yield loss of 1% for maize and wheat (Ortiz-Bobea et al., 2019[44]). Finaly, heat stress prone locations for livestock are areas where the average number of days with an average daily Temperature-Humidity Index (THI) above 69 has increased between the reference period and 2015–2020, based on studies showing that livestock productivity starts to decrease above this THI value (Gisbert-Queral et al., 2021[45]; North et al., 2023[17]).

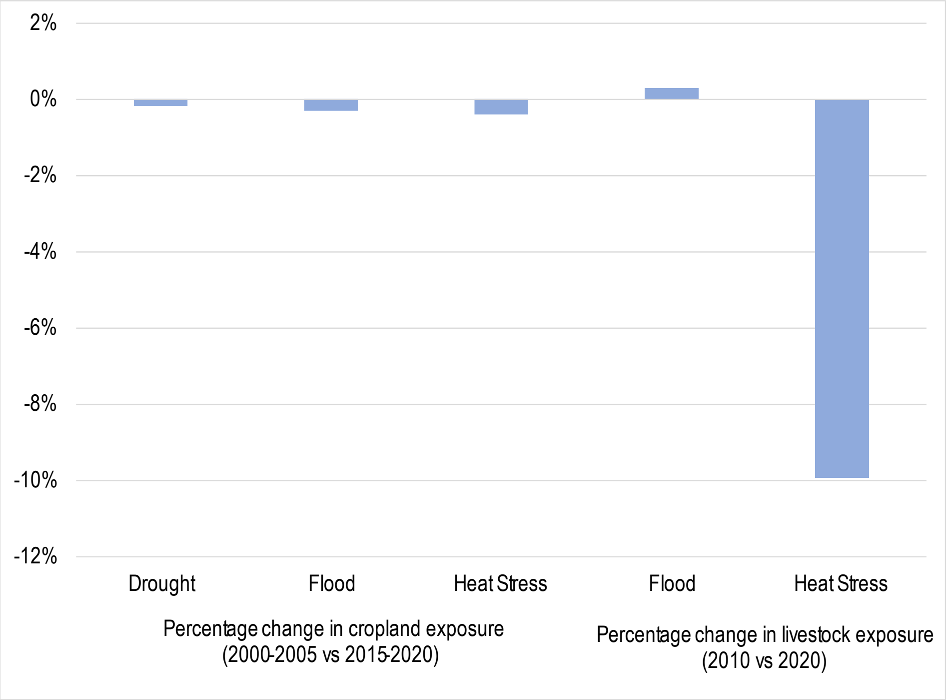
Identifying shifts in cropland or livestock production away from areas at risk can provide insights on adaptive behaviours. Relocating production helps reduce future impacts of extreme weather events by avoiding high-risk areas while also capitalising on improved agricultural conditions arising from changing weather conditions. Building on historical hazard data, these indicators can capture reactive responses to observed changes in average weather conditions, which are assumed to elicit stronger reactions than future, uncertain risks. The indicators measure the annual share of a country's total harvested cropland area – defined as land covered with temporary crops followed by a harvest and a period of bare soil - or total Livestock Unit (LSU)^3 located in areas at-risk during the period 2000–2020. Since risk-prone areas remains identical over this 20-year period, changes in the indicator's value between two periods is consequent to a shift in production location. As the indicator control for total cropland area or overall Livestock Unit, a decrease in exposure (indicated by a negative change) may result from: (1) a "reallocation" of production to safer areas, (2) the expansion of agriculture primarily in safer zones, and/or (3) a decrease in the production in high-risk areas.

4.1.2. Results

Change in cropland location led to a slight decrease in the exposure of OECD crop production to floods, droughts and heat stress between the periods 2000-2005 and 2015-2020. Over the past two decades, the share of OECD cropland located in exposed areas has declined (Figure 4.1). Similarly, the proportion of OECD livestock located in heat stress prone areas dropped by around 10% between 2010 and 2020, largely driven by a significant reduction in livestock exposure in the United States, which accounts for 30% of OECD livestock units. Finally, livestock exposure to floods saw a slight increase (+0.3%) over the same period. However, these aggregated figures mask strong heterogeneity between OECD countries. For example, shifts in the share of country's cropland exposure to droughts, floods and heat-stress varies from [-8.7%;10%], [-7.7%;4.6%] and [-5.9%; 10.8%] respectively between the periods 2000-2005 and 2015-2020. These changes are not solely driven by fluctuations in the total area of cultivated land at risk but are primarily influenced by how agricultural expansion or contraction is distributed between exposed and non-exposed areas (Figure A C.1).

Figure 4.1. Change in OECD cropland and livestock exposure to drought, flood and heat stress

Percentage change in the average share of OECD cropland area and livestock unit located in flood, heat stress and drought (cropland only) prone areas, between the periods 2000-2005 and 2015-2020 (cropland) and the years 2010 and 2020 (livestock).



Source: Authors' own, using: Cropland: OECD process Copernicus Global Land Cover data (Copernicus Climate Change Service, 2019[38]); Livestock: Gridded Livestock of the World GLW v4 (Gilbert et al., 2018[42]); Drought: Soil moisture gridded data (Copernicus Climate Change Service, 2018[39]); Heat stress: ERA5-Land hourly data (Muñoz Sabater, J., 2019[41]) for cropland and ERA5-Land post-processed daily statistics (Copernicus Climate Change Service, 2024[43]) for livestock; Flood: Global river flood hazard maps (Baugh et al., 2024[40]).

4.2. Dimension II: Resilient Agricultural Practices Reducing Vulnerability

4.2.1. Description of indicators

The suggested list of indicators aims to measure progress in the adoption of adaptation measures and practices through the adjustment in species grown, the implementation of infrastructure and technology and the change in water use in agriculture (Table 4.2)**.** The broad diversity of adaptation solutions to reduce vulnerability and the data required for their analysis make it challenging to develop a more comprehensive and exhaustive set of indicators. Key barriers to their inclusion include the lack of consistent, recurring data over time and the limited geographical coverage of available datasets.

The adaptation of the agricultural sector through changes in cultivated species is assessed by analysing the diversity of national crop and livestock production and the suitability of cultivated crops to local weather conditions. Greater diversity of agricultural production enhances resilience at both farm and national levels, reducing vulnerability to extreme weather events (Lin, 2011[46]). Crop and livestock production diversity is measured using the Shannon Index, a widely adopted metric for assessing the diversity of agricultural and economic production (Schaak et al., 2023[47]). This index quantifies crop diversity based on the number of different crops grown in a country and their proportional share of total country's cultivated land, using FAO primary crops production data covering 151 crop types (FAO, 2024[48]). Livestock diversity is calculated in a similar way, using the number of livestock species and their relative share in total country's Livestock Unit,[3] among 15 livestock species raised for meat and/or milk, including five species bred for both purposes (buffalo, camel, cattle, sheep, and goat) (FAO, 2024[48]). A higher Shannon Index value indicates greater diversity of the production. The suitability of agricultural production to local weather conditions is assessed by combining the FAO Global Agro-Ecological Zones (GAEZ) crop suitability index (FAO and IIASA, 2022[49]) - which rates each area from not suitable to very suitable for various type of crops - with the gridded data[4] on 42 crop types location from the Spatial Production Allocation Model (SPAM)[5] (You et al., 2014[50]). This indicator represents the proportion of countries' agricultural area where the types of crops grown are classified from moderately to very suitable to local weather conditions.

The progress in the adoption of adaptation technology and infrastructure is monitored through the development of irrigation. The growing risk of drought driven by changing weather conditions and extreme weather events and the value-added of irrigated crops can encourage the adoption of irrigation to sustain agricultural productivity. While irrigation is an effective strategy for mitigating the impact of water stress on crop yields (IPCC, 2022[1]), its expansion can intensify pressure on already scarce water resources in many regions. Consequently, some countries, such as Spain or Austria, make the development of more efficient, water- saving irrigation systems key components of their adaptation strategy for the agricultural sector (BMK, 2024[27]; Gobierno de España, 2020[30]). In the absence of data on irrigation efficiency or detailed information on irrigation types (e.g. surface, sprinkler or drip irrigation), this indicator evaluates irrigation development by calculating the area of cropland equipped for irrigation.

Table 4.2. Indicators for dimension II: Resilient Agricultural Practices Reducing Vulnerability

Domain	Indicator	Description	Data
Change in species/products	Diversity of crop production	National level Shannon index, based on number of different crops produced by the country and the relative area devoted to each.	Crops and livestock products (FAO, 2024[48])
	Diversity of livestock production	National level Shannon index, based on number of different livestock species bred in the country and the relative Livestock Unit represented by each.	Crops and livestock products (FAO, 2024[48])
	Crop suitability	Share of country's total agricultural area where the crops grown are suitable to local conditions	SPAM (IFPRI (2024[51]) and (2019[52])) and GAEZ (FAO and IIASA, 2022[49])
Infrastructure & technology	Development of irrigation	Cropland area equipped for irrigation (ha)	AQUASTAT (FAO, 2021[53])
Consequences of change in measures and practices	Water withdrawal for irrigation	Volume of water withdrawal for irrigation per unit of cropland area ($m^3.ha^{-1}$)	Freshwater-Abstractions (OECD, 2024[54]) and AQUASTAT (FAO, 2021[53])
	Water intensity of crop production	Average national water footprint of crop production ($m^3.ha^{-1}$)	(Mialyk et al., 2024[55])

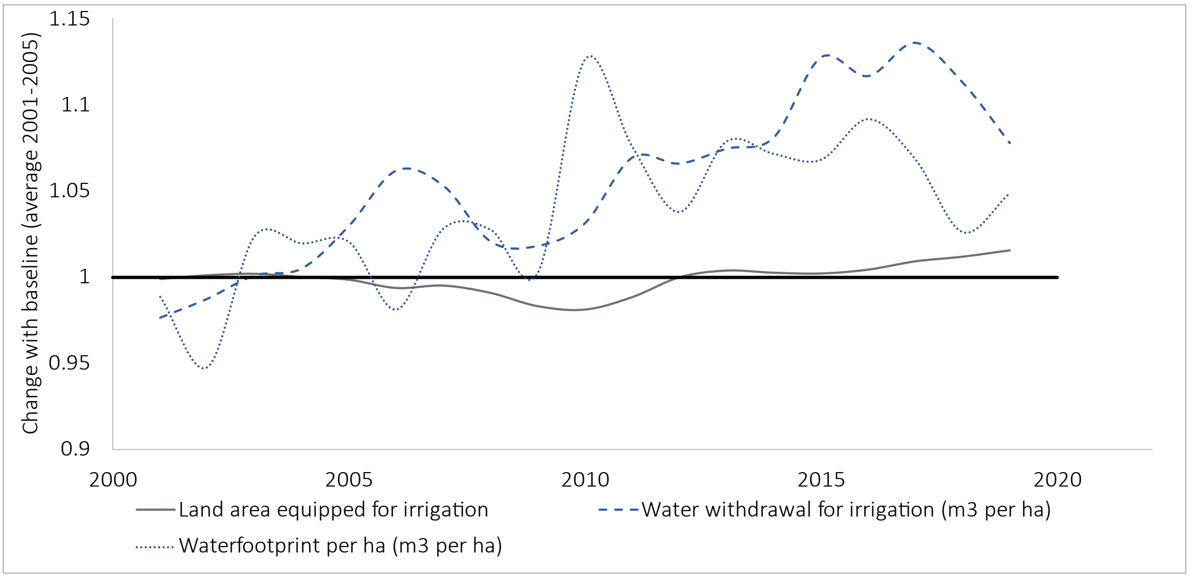
Agricultural water intensity is measured by monitoring irrigation withdrawals and the total water footprint of production. Reducing the water intensity of the agricultural sector is a priority for many OECD countries. Various adaptation solutions, such as more efficient irrigation or changes in crop species, aim to reduce water consumption in agriculture. Water use for irrigation is measured as the volume of water withdrawal for irrigation per unit of cropland. OECD data on irrigation water withdrawals (OECD, 2024[54]) are primarily used and completed by FAO data if need be[6] (FAO, 2021[53]). The total water footprint of a country's agricultural production signals the total water needs for crop production. It is assessed using annual national water footprint indicator from Mialyk et al. (2024[55]), which averages water footprint by crop type and by country. Annual crop- and country-specific water footprints are derived from a crop model that accounts for local weather, crop traits, and farming practices.

4.2.2. Results

Despite limited irrigation development over the past 20 years, agricultural water use and needs have steadily risen. Focusing on 21 OECD countries,[7] Figure 4.2 shows that the area equipped for irrigation expanded by less than 2% between 2000 and 2020. The development of irrigation capacity is strongly correlated with country's investment in hydrological infrastructure (Figure A C.2 in the appendix). However, both the total water footprint of crop production and irrigation water withdrawal per hectare have followed a nearly linear upward trend since 2000, reaching approximately 5% and 8% above the 2000–2005 average by 2020, respectively. This rising water footprint reflects growing agricultural water demand, primarily driven by the cultivation of more water-intensive crops (Mialyk et al., 2024[56]), and the gap between rising water demand and minimal irrigation expansion indicates that farmers are mostly cultivating water-intensive crops in areas already equipped for irrigation. The parallel trends between water use and water footprint, along with the limited development of irrigation capacity, suggests limited progress in improving irrigation efficiency, contrary to the adaptation goals of many OECD countries, or that these gains are partially offset by soil drying and changing environmental conditions. However, these observations should be interpreted with caution, as assessing progress in irrigation efficiency would require deeper analysis of how irrigation systems are being utilized and average trends in water use mask significant cross-country variation. For example, the United States recorded an 18% decrease in water withdrawals for irrigation between 2000–2005 and 2015–2020 (Table A B.2).

Figure 4.2. Irrigation capacity and water intensity of OECD agricultural production

Evolution of total cropland area equipped for irrigation, water footprint of crop production and water withdrawal for irrigation in 21 OECD countries, compared with baseline average 2001-2005

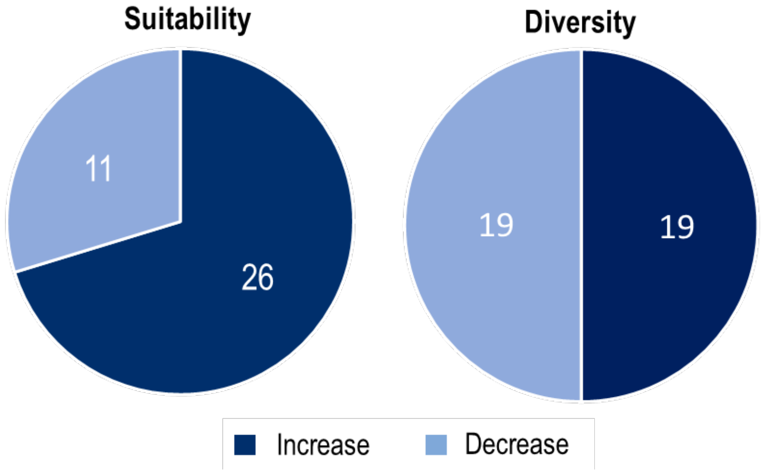


Note: This figure is limited to OECD countries for which annual estimates of irrigation capacity, water withdrawal for irrigation and water footprint are available for all years in the period 2001-2019. The 21 OECD countries included are: Austria, Canada, Colombia, Denmark, Estonia, Finland, France, Hungary, Italy, Japan, Latvia, Lithuania, New Zealand, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, USA.
Source: Authors' own, using (OECD, 2024[54]), AQUASTAT (FAO, 2021[53]), and (Mialyk et al., 2024[55]).

Diversity of crop production and its suitability to local environmental conditions increased in many OECD countries over the last two decades. Most crops in the OECD are well-suited to the environmental conditions of their growing regions, with 91.7% of OECD cropland cultivating crops that were well adapted to local conditions in 2020. The suitability increased in more than two third of OECD countries over the period 2000-2020 (Figure 4.3), by up to 32% (Table A B.2). However, changes in the diversity of national crop production present a more nuanced picture. While half of OECD countries have seen an increase in production diversity (as indicated by a higher Shannon Index value), the other half have become more specialized over the same period. Although the number of distinct crop types grown has increased in almost all OECD countries, shifts in crop production diversity are primarily driven by change in the concentration of cropland allocation toward most cultivated crops (see Figure A C.3). This trend aligns with global studies suggesting that the growing demand for more diverse agricultural products is largely met through trade rather than changes in domestic agricultural production (Aguiar et al., 2020[57]). However, the diversity of livestock production declined for two-thirds of OECD countries between the periods 2000-2005 and 2015-2020 (Table A B.2).

Figure 4.3 Crop production diversity and local weather conditions suitability

Number of OECD countries experiencing an increase (decrease) in the share of cropland area cultivating crops suitable to local weather conditions and in the Shannon crop production diversity index between the periods 2015-2020 and 2000-2005



Note: The change in crop suitability is assessed by comparing crop location from SPAM data in 2005 and in 2020.
Source: Authors' own, using data from SPAM (IFPRI (2024[51]) and (2019[52])), GAEZ (FAO and IIASA, 2022[49]) and Crops and livestock products (FAO, 2024[48]).

4.3. Dimension III: Impacts of Extreme Weather Events on Agriculture

4.3.1. Description of indicators

Selected indicators target the impact of extreme weather events on the agricultural production (Table 4.3)**.** The yearly fluctuation in crop, meat and milk yields is used as a proxy to assess the resilience of a country's crops, meat and dairy production to weather shocks.

Table 4.3. Indicators for dimension III: impacts of extreme weather events on agricultural production

Domain	Indicator	Description	Data
Quantity of production	Crop, milk and meat yield fluctuation	Percentage deviation of annual yield from the average annual yields of the 6 preceding years	Crops and livestock products (FAO, 2024[48])

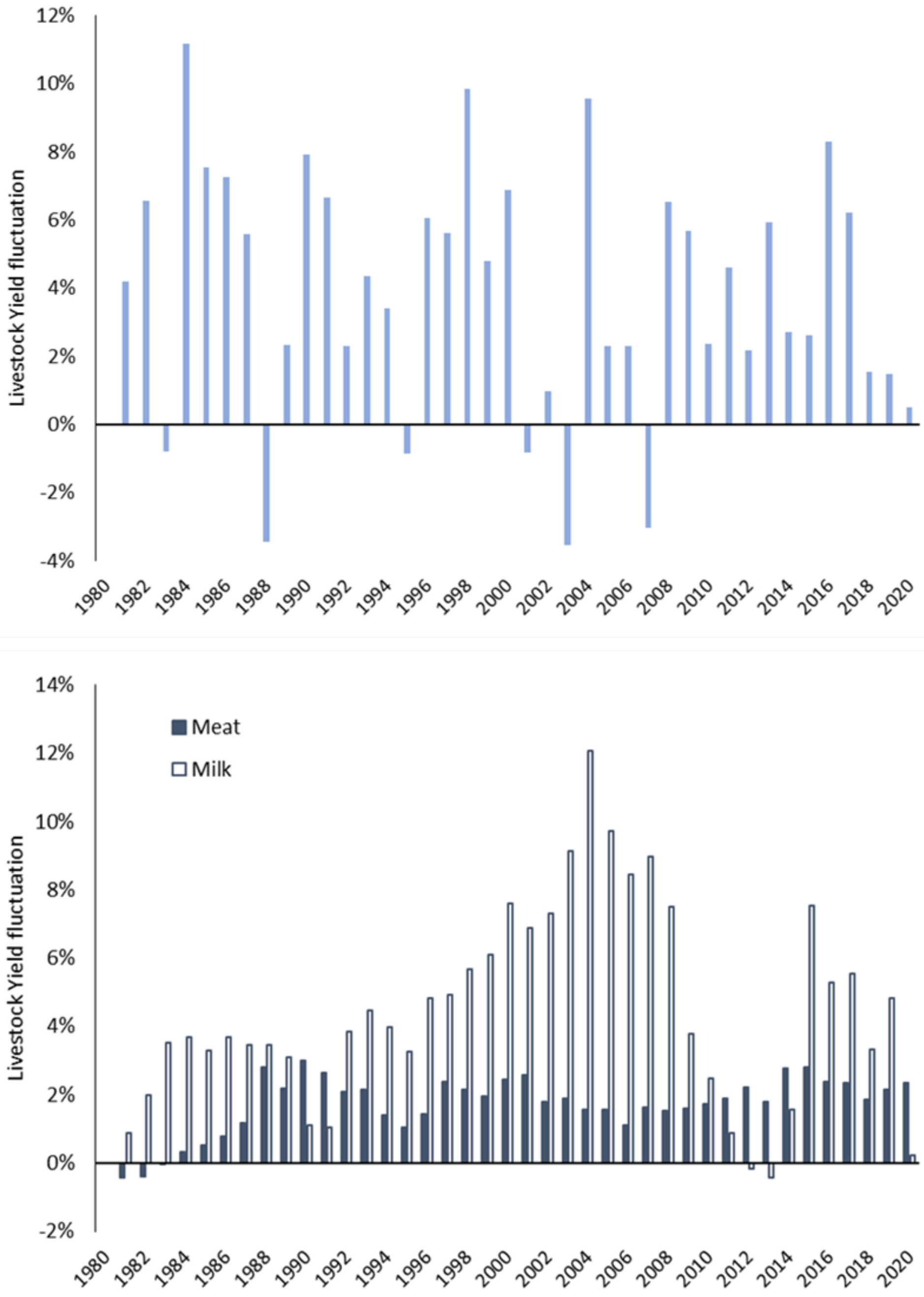
The yield fluctuations' indicators represent the weighted average changes in crop and livestock yield across all crops grown and livestock species reared in a country. While many factors influence the variation of crop yields (e.g. irrigation, use of fertilizers, crop selection), weather conditions account for around a third of this variability (Ray et al., 2015[58]). Similarly, diary and meat productions are highly sensitive to weather conditions (Nardone et al., 2006[59]; Gisbert-Queral et al., 2021[45]; North et al., 2023[60]). Thus, monitoring these fluctuations can provide valuable insights into the resilience of agricultural production to weather shocks. The crop yield indicator is calculated by summing the annual yield variation for each crop (measured as the relative difference between its annual yield and the average yield of the previous six years) weighted by the crop's share of the country's total harvested area. It is inspired by the crop specific yield fluctuation indicator used by Germany in its 2023 Monitoring Report on the German Strategy for Adaptation to Climate Change (Umwelt Bundesamt, 2023[61]). The meat and milk yield indicators are calculated similarly, as the annual variation in meat or milk production for each species relative to its six-year average, weighted by its share of the total number of producing animals.

4.3.2. Results

Over the period 1981–2020, average yields have shown a continuous upward trend in the OECD. Positive inter-annual fluctuations in yields indicate steady increases in average agricultural output (tons per hectare or per number of producing animals) over the past 20 years (Figure 4.4). These positive fluctuations reflect a sustained rise in crop and livestock productivity, driven by advancements in farming techniques, livestock genetics and crop breeding that have significantly improved the efficiency of agricultural inputs (USDA, 2024[62]). However, lower values in crop yield fluctuations observed in 2018, 2019 and 2020 suggest a stagnation in crop productivity. Concurrently, many OECD countries have experienced an increase in negative crop yield deviations over the period 2000-2020, reflecting heightened sensitivity to external shocks, including extreme weather events. For instance, between 1981 and 2020, Germany and France recorded 12 and 11 years of below-average yields, respectively, with 10 of these years in Germany and 9 in France occurring after 2000 (Figure A C.4).

Figure 4.4. Crops, milk and meat yields fluctuation in the OECD

Deviation of average weighted OECD crops, milk and meat annual yields with previous 6 years yields average (1981-2020)



Note: OECD level annual yields are computed as the ration between the total annual production (in tons) over all OECD countries divided by the OECD total cropland area (in ha) or the total number of producing animals. The weighted average fluctuation in OECD crop yields is calculated by summing, across all crops grown in the OECD, the annual yield variation for each crop (measured as the difference between its annual yield and the average yield of the previous six years, expressed as a percentage of that six-year average) multiplied by the crop's share of the total harvested area in all OECD countries. The types of crops are identified among the 151 "primary crop" types identified in the Crops and livestock products database of the FAO grown in OECD countries. Livestock species include asses, cattle, chickens, pig, pigeons and other birds, mules, goat, geese, ducks, rabbits and hares, buffalo, camels, sheep and turkeys for meat and buffalo, cattle, sheep and goat for milk.
Source: Authors' own, using (FAO, 2024[48]).

4.4. Dimension IV: Enabling Agricultural Adaptation

The suggested indicators assess progress towards the establishment of an enabling environment for adaptation along three aspects: the innovation in agricultural adaptation technologies, the planning for adaptation in the agricultural sector and the implementation of adaptation programmes and policies targeting the agricultural sector (Table 4.4)**.** These two first indicators belong respectively to the resources and the planning and coordination sub-categories of the fourth dimension of the measurement framework described in section 2, while the last indicator measures overall efforts in setting an enabling environment.

Table 4.4. Indicators for dimension IV: enabling agricultural adaptation

Domain	Indicator	Description	Data
Resources	Innovation in agricultural adaptation technologies	Share of annual agricultural adaptation inventions in all agricultural inventions	Patent data (OECD, 2024[63])
Planning and coordination	Adaptation planning in the agricultural sector	Index (value from 0 to 10) representing the extent to which planning for adaptation in the agricultural sector is detailed in the last NAPs, NAS or agricultural adaptation plan	NAPs, NAS or sectoral adaptation plans (Table A B.4)
Implementation of adaptation policies	Adaptation policies and programmes targeting the agricultural sector	Number (stock) of adaptation programmes and policies that target the agricultural sector	2023 Agricultural Policy and Monitoring (OECD, 2023[8]).

Patenting activity in agricultural adaptation is used as a proxy for the innovation in adaptation technologies. This indicator represents the number of agricultural adaptation patents invented in a country as a share of all agricultural patent invented in this country. It assesses innovation in adaptation technologies controlling for trends in patenting in the agricultural sector as a whole. Patents are used to protect inventions of public and private entities in countries where they are filed, and widely used in the academic literature as a proxy for technological innovation (Touboul, 2021[64]; Leflaive, Krieble and Smythe, 2020[65]; Haščič and Migotto, 2015[66]). Patent documents contain information on the home country of the inventor, used as a proxy for the country where the technology has been invented. Patent data are extracted from the OECD Science Technology and Innovation (STI) Micro-data Lab's Intellectual Property Database, which is based on information from the World Patent Statistical Database (PATSTAT) maintained by the European Patent Office (OECD, 2024[63]). CPC codes are used to identified patents belonging to adaptation in the agricultural sector (Y02A40)[8] and to the agricultural sector as a whole (A01). Progress towards the development of funding mechanisms for adaptation, as well as training and education of workers regarding adaptation issues cannot be covered due to lack of data.

Planning for adaptation in the agricultural sector is assessed by reviewing the extent to which adaptation strategy for the agricultural sector is detailed in official national planning documents. This indicator is based on a review of the last country's National Adaptation Plans (NAP) or Strategies (NAS), or agricultural national adaptation plans when they exist. All these plans serve as references for OECD countries to set and communicate on their national adaptation objectives and recommend actions. As NAPs or NAS cover multiple sectors and stakeholders, these documents also allow countries to communicate on their adaptation plans to a broad and multi sectorial audience, enforcing a common understanding of the issue. The indicator is an index developed for the purpose of this paper, rated from 0 to 10, based on several criteria that reflect the level of detail in adaptation planning for the agricultural sector (Table 4.5). Analysing how adaptation to extreme weather events is mainstreamed into other key sectoral documents (e.g. agriculture development plans) would also be critical, but such reference document for the agricultural sector does not exist for all OECD countries.

The final indicator takes stock of adaptation policies and programmes related to agriculture implemented by OECD countries. This indicator reflects the number of adaptation programmes and activities self-reported by OECD countries in their official communications to the UNFCCC. The data is sourced from the analysis conducted in the 2023 Agricultural Policy and Monitoring report (OECD, 2023[8]). It reflects countries' overall efforts to create an enabling environment for adaptation. It may also address aspects of the enabling environment that overlap with other indicators, such as planning and knowledge creation.

Table 4.5. Scoring criteria for the adaptation planning index

Score	Criteria
NA	No NAP/NAS or sectoral adaptation plan
0	Agriculture is not mentioned in the NAP/NAS and no sectoral adaptation plan exists
1	Agriculture is mentioned in the NAP/NAS or a sectoral adaptation plan exists
2	Specific objective(s) for agriculture are detailed in the document
3 - 10	One additional point for each of the below criteria meet: - Adaptation options and actions are identified - Objective(s) or action(s) are timebound[a] - Objective(s) or action(s) are measurable[b] - Objective(s) and action(s) are based on a risk assessment[c] - Available resources are identified and/or dedicated (funding, but also capacity building)[d] - Identification of entities responsible for taking action/fulfilling the objective(s)[e] - Mechanisms or entities are identified to ensure cross sectoral and multi-level coordination[f] - Monitoring and evaluation processes are identified[g]

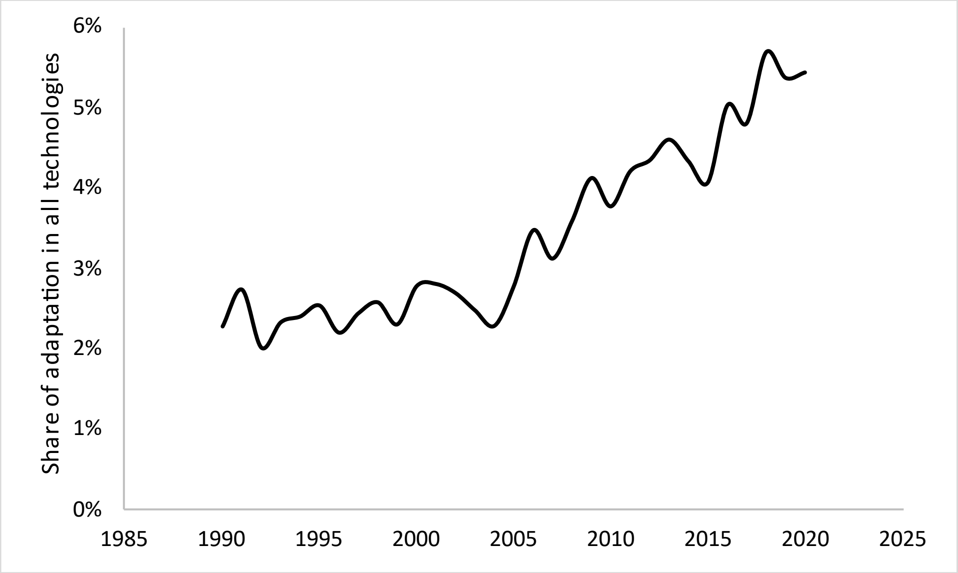
Note: The acronyms "NAP" stands for National Adaptation Plan, and "NAS" for National Adaptation Strategy. For the section "3-10", compliance with one criterion is assigned one additional point. 0.5 points can be attributed if the criterion is not fully met: a) if only some objectives are timebound or if the deadlines are defined in qualitative terms only (e.g. short term, medium term, long term are awarded for criteria; b) if only some of the objectives and actions are measurable; c) if the climate risk assessment exist but does not detail risks or impacts for agriculture specifically; d) if resources that have already been allocated are mentioned, and/or if funding needs are identified without specifying the sources (and vice versa); e) if responsibilities are defined for a limited number of stakeholders (e.g. some national ministries only) or for some objective(s) or action(s) only; f) if the necessity for cross-sectoral or multi-level coordination is acknowledge in the NAP but no coordination body nor cross-sectoral objective(s) are defined; g) if the plan contains information or a section on monitoring, reporting or evaluation but does not fully qualify the reporting/monitoring system, or the system is detailed but not in place yet.

4.4.1. Results

Innovation in agricultural adaptation technologies has increased over the last 20 years. The share of agricultural technologies related to adaptation on all agricultural technologies invented has almost tripled in OECD countries during the period 1990-2020, signaling an increase in innovation dedicated to adaptation technologies specifically (Figure 4.5). This trend is common to most OECD countries, as only four of them have experienced a decrease in their specialization into adaptation technologies between the periods 2000-2005 and 2015-2020 (Table A B.4).

Figure 4.5. Increase in innovation in agricultural adaptation technologies in the OECD

Share of agricultural adaptation patents in all agricultural patents filed in OECD countries (1990-2020)

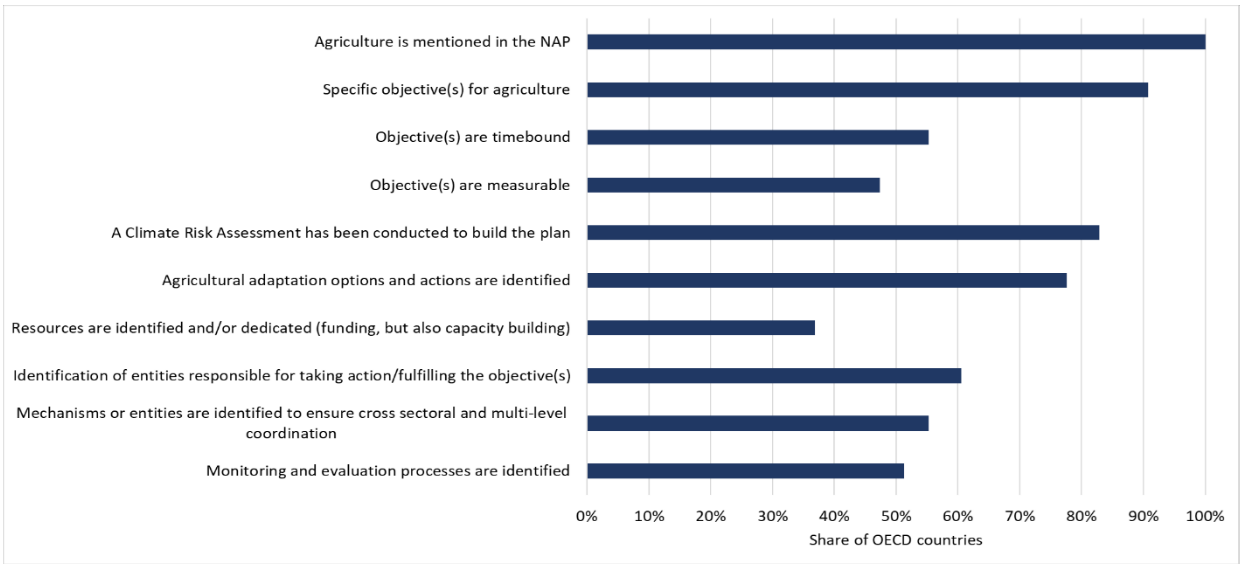


Note: Adaptation agricultural and overall agricultural technologies are identified using PATSTAT CPC classification. PATSTAT CPC codes are used to identified patents belonging to adaptation in the agricultural sector (Y02A40)[9] and to the agricultural sector as a whole (A01).
Source: Authors' own, using data from (OECD, 2024[63]).

All OECD countries acknowledge agriculture as a priority in their adaptation plans, but most lack the comprehensiveness needed to fully guide and coordinate actions. All OECD countries reference agriculture as a key sector in their National Adaptation Plans (or Strategies) and some go further by developing sector-specific adaptation plans for agriculture. Most countries set clear adaptation goals for agriculture, and over 75% turn these objectives into concrete actions. Similarly, more than 80% of OECD countries provide details on the climate risk assessment for agriculture to inform their plans. (Figure 4.6). However, turning plans into action remains a challenge: only a third identify adaptation funding needs and sources for agriculture in their planning document, and 40% do not specify entities responsible for implementation and oversight. In addition, only half of OECD countries have defined timebound and measurable objectives, or outline clear monitoring rules, making it difficult to track progress or assess the success of adaptation efforts (Figure 4.6).

Figure 4.6. Integration of Agriculture into National Adaptation Plans

Proportion of OECD countries incorporating each criterion of the adaptation planning index in their national adaptation plans, strategies or agriculture-specific adaptation plans.

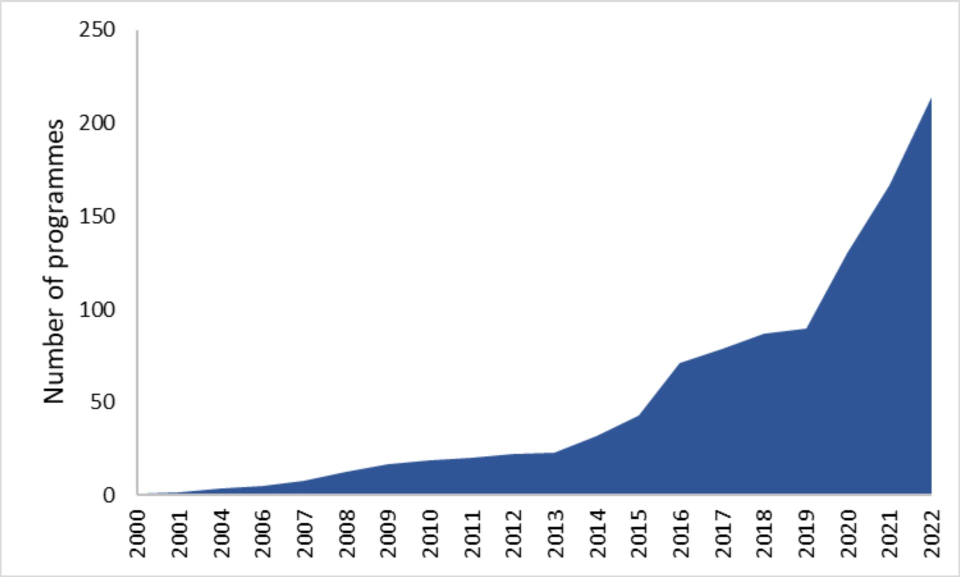


Note: Table A B.4 in appendix B details the planning document reviewed for each country. The proportion for each criteria is computed as the sum of each country score divided by the number of OECD countries (38).
Source: Authors own, based on the documents listed in Annex B.

The increase in the number of adaptation related programmes highlights the rising awareness of OECD governments of the need to act to build a more resilient agricultural sector. The stock of adaptation programmes reported by OECD countries in their UNFCCC communications[10] has grown exponentially over the last 20 years (Figure 4.7). Almost 60% of the adaptation programmes that could be dated to the 2000-2022 period - 214 out of the 393 OECD countries' programmes reported by the OECD (2023[8]) - were created between 2020 and 2022. Planning, capacity building (e.g. organisation of training and workshops, technical assistance for farmers) and climate services (e.g. creation of national climate events or soil health databases, deployment of early warning systems) related programmes represent half of the reported activities, completed by investments for the development of infrastructure (e.g. irrigation), technologies, ecosystem-based solutions (e.g. agroecology) and change in agricultural practices (e.g. crop and livestock management practices) (OECD, 2023[8]).

Figure 4.7. Sharp increase in the number of national adaptation programmes for agriculture

Stock of adaptation programmes related to agriculture created over the period 2000-2020, as reported by OECD countries in their UNFCCC communications.



Note: This figure only reports programmes that could be dated by the Authors' own, i.e. 214 out of the 393 OECD countries' programmes reported by the Agricultural Policy Monitoring and Evaluation 2023. UNFCCC communications include National Communications (NC), Nationally Determined Contributions (NDCs) and Adaptation Communications.
Source: Authors own, using data from (OECD, 2023[8]).

Annex A. Indicator sheets

This annex details the rationale, methodology and data used to build each of the indicators presented in this document.

Dimension I: Cropland exposure to drought

Description

Drought, by reducing soil moisture, is recognized as a major factor negatively impacting both the quantity and quality of the agricultural production. Drought-related yield losses have affected approximately 75% of the global cropland area from 1983 to 2009, with an upward trend in recent years (IPCC, 2022[1]). Overall drought-driven yield loss is estimated to increase by 9–12% (wheat), 5.6–6.3% (maize), 18.1–19.4% (rice) and 15.1–16.1% (soybean) by 2071–2100, relative to 1961–2016 (RCP8.5) (IPCC, 2022[1]). Moreover, water stress induced by droughts reduces metabolic processes of crops responsible for producing soluble sugars, proteins, starch, and lipids, and impact crops quality (Stagnari, Galieni and Pisante, 2016[67]).

Adapting to extreme weather events may require changes in crop allocation or limit agriculture expansion in drought prone areas to reduce agricultural production exposure to droughts. A study showed that if crop locations remain unchanged by 2070 under RCP8.5, agricultural profits for six crops will drop by 31% in the United States due to changing temperature and precipitation pattern. However, reallocating croplands could cut these losses by half (16%) (Rising and Devineni, 2020[20]).

This indicator aims to measure progress in reducing cropland exposure to drought by assessing changes in country's cropland area located in drought prone area due to a change in cropland location. Global land use gridded data is used to identify cropland areas (Copernicus Climate Change Service, 2019[38]). Using daily average soil moisture gridded data, drought prone areas are identified as areas where the number of days with soil moisture below 200kg/m3 increased by four days or more during the growing season between the reference period (1980-2010) and 2015-2020, threshold corresponding to a 1% decrease in crops yields (Ortiz-Bobea et al., 2019[44]). $d_c(x)$ is a binary variable equal to 1 if area x of country c is classified as a drought prone area:

$$d_c(x) = \begin{cases} 1 \text{ if count of days with soil moisture below } 200 \text{ kg/m}^3 \text{ increased by at least 4 days during} \\ \qquad \text{the growing season between 1980-2010 and 2015-2020 in area } x \text{ } of \text{ country } c, \\ 0 \text{ otherwise} \end{cases}$$

The total area of cropland in country c exposed to drought risk at year t, denoted as $Dcrop_{c,t}$, equals:

$$Dcrop_{c,t} = \sum\nolimits_{x \in \text{cropland in } c \text{ } at \text{ } t} d_c(x) * a(x), \text{ with } a(x) \text{ the surface of cropland in area } x.$$

The share of cropland exposed to drought risk in country c at time t ($Sh\_Dcrop_{t,c}$) is calculated as:

$$Sh\_Dcrop_{c,t} = \frac{Dcrop_{c,t}}{Acrop_{c,t}}, \text{ with } Acrop_{c,t} \text{ the total cropland area in country } c \text{ at time } t.$$

Data

No.	Data	Source	Temporal scope & resolution	Country coverage	Description	Technical characteristics
1	Land cover	Copernicus Global Land Cover (Copernicus Climate Change Service, 2019[38]), processed by OECD	2000-2022, Annual	Global	The original 22 land cover classes have been aggregated into a 6-level land classification. Land cover classes 10, 11, 12, 20, 30, and 40 correspond to cropland.	TIFF, 300m resolution
2	Soil Moisture	Copernicus Climate Change Service	1981-2022, Daily	Global	Volumetric soil moisture in the top 2 to 5 cm layer of soil (m^3/m^3)	TIFF, 0.25 degree resolution

Indicators

No.	Indicator description	Temporal scope & resolution	Country coverage
1	Share of country's cropland area located in drought prone areas	2000-2022, Annual	Global

Dimension I: Cropland exposure to flood risk

Description

Global increase in flood risks appears as one of the main threats for agricultural production. Floods with a return period exceeding ten years caused average global annual yield losses of 4% for soybeans, 3% for rice, 2% for wheat, and 1% for maize over the period 1951–2010 (Kim et al., 2023[68]). Floods damage agricultural production by directly affecting crops, soil, machinery, and infrastructure (Brémond and Grelot, 2013[69]) and by delaying planting as well as other farming operations (IPCC, 2022[1]). Projected global temperature rises of 1.5°C are expected to lead to an increase in flooding events that surpass the capacity of existing flood protection measures (IPCC, 2022[70]).

Adapting to extreme weather events may thus require changes in crop allocation or to limit agriculture expansion in flood prone areas to reduce agricultural production exposure to floods. A study showed that if crop locations remain unchanged by 2070 under RCP8.5, agricultural productivity for six crops will drop by 31% in the United States due to changing temperature and precipitation pattern (Rising and Devineni, 2020[20]). However, reallocating croplands could cut these losses by half (16%).

This indicator aims to capture the change in cropland exposure to flood risk due to change in crop location. Global land use gridded data is used to identify cropland areas (Copernicus Climate Change Service, 2019[38]). The global river flood hazard depth maps published by the European Commission's Joint Research Centre are used to identify cropland exposed to flood risk (Baugh et al., 2024[40]). 10-year return period floods over the 1979-2013 period are considered due to their significant impact and frequent occurrence, making them a common return reference period in several studies (IPCC, 2023[71]). The global river flood hazard depth maps are converted into binary data $f_c(x)$ indicating the presence or absence of flood risk in area x, defined as:

$$f_c(x) = \begin{cases} 1 \text{ if the 10-year return period flood exceeds zero in area } x \text{ in country } c \\ 0 \text{ otherwise} \end{cases}$$

The total area of cropland in country c exposed to flood risk at year t, denoted as $Fcrop_{c,t}$.

$$Fcrop_{c,t} = \sum_{x \in \text{cropland in } c \text{ } at \text{ } t} f_c(x) * a(x), \text{ with } a(x) \text{ the surface of cropland in area } x.$$

The share of cropland exposed to flood risk in country c at time t ($Sh\_Fcrop_{t,c}$) is calculated as:

$$Sh\_Fcrop_{c,t} = \frac{Fcrop_{c,t}}{Acrop_{c,t}}, \text{ with } Acrop_{c,t} \text{ the total cropland area in country } c \text{ at time } t.$$

Data

No.	Data	Source	Temporal scope & resolution	Country coverage	Description	Technical characteristics
1	Land cover	Copernicus Global Land Cover (Copernicus Climate Change Service, 2019[38]), processed by OECD	2000-2022, Annual	Global	The original 22 land cover classes have been aggregated into a 6-level land classification. Land cover classes 10, 11, 12, 20, 30, and 40 correspond to cropland.	TIFF, 300m resolution
2	Flood risk	Global river flood hazard maps (Baugh et al., 2024[40]).	10-year return period risk based on 1979-2013	Global	Flood depth along the river network for seven different flood return periods (from 1-in-10-years to 1-in-500-years).	TIFF, 3 arc seconds resolution

Indicator

No.	Indicator description	Temporal scope & resolution	Country coverage
1	Share of country's cropland area exposed to 10-year return period flood risk	2000-2022, Annual	Global

Dimension I: Cropland exposure to heat stress

Description

Temperature is a key environmental factor influencing crop growth, development, and yields. While the impact varies by region and crop type, rising temperatures consistently led to yield losses. A 1°C increase reduces global average maize yields by 7%, rice and soybean by 3% and wheat by around 5% (Khan et al., 2023[72]). As a consequence, food production systems may face significant negative impacts under 2°C warming by the late 20th century, with temperatures above 4°C posing even greater threats to global food security (IPCC, 2022[1]).

Adapting to extreme weather events may thus require changes in crop allocation or to limit agriculture expansion in areas where temperatures are rising significantly to reduce agricultural production exposure to heat stress. A study showed that if crop locations remain unchanged by 2070 under RCP8.5, agricultural profits for six crops will drop by 31%. However, reallocating croplands could cut these losses by half (16%) (Rising and Devineni, 2020[20]).

This indicator aims to capture the change in cropland exposure to heat stress due to change in crop location. Global land use gridded data is used to identify cropland areas (Copernicus Climate Change Service, 2019[38]). Heat-stress areas for cropland are determined as regions where the number of hours above 30°C during the growing season increased by more than 44 hours between the reference period (1980-2010) and 2015–2020, a threshold associated with an average yield loss of 1% for maize and wheat (Ortiz-Bobea et al., 2019[44]). $h_c(x)$ is a binary variable equal to 1 if area x of country c is classified as a heat-stress prone area:

$$h_c(x) = \begin{cases} 1 \text{ if count of hours with temperature over 30°C increased by 44 hours during} \\ \text{the growing season between 1980-2010 and 2015-2020 in area } x \; of \text{ country } c, \\ 0 \text{ otherwise} \end{cases}$$

The total area of cropland in country c exposed to heat stress risk at year t, denoted as $Hcrop_{c,t}$.

$$Hcrop_{c,t} = \sum_{x \in \text{cropland in } c \text{ } at \text{ } t} h_c(x) * a(x), \text{ with } a(x) \text{ the surface of cropland in area } x.$$

The share of cropland exposed to heat stress in country c at time t ($Sh\_Hcrop_{c,t}$) is calculated as:

$$Sh\_Hcrop_{c,t} = \frac{Hcrop_{c,t}}{Acrop_{c,t}}, \text{ with } Acrop_{c,t} \text{ the total cropland area in country } c \text{ at time } t.$$

Data

No.	Data	Source	Temporal scope & resolution	Country coverage	Description	Technical characteristics
1	Land cover	Copernicus Global Land Cover (Copernicus Climate Change Service, 2019[38]), processed by OECD	2000-2022, Annual	Global	The original 22 land cover classes have been aggregated into a 6-level land classification. Land cover classes 10, 11, 12, 20, 30, and 40 correspond to cropland.	TIFF, 300m resolution
2	Temperature	ERA5-Land hourly data (Muñoz Sabater, J., 2019[41])	1950-present, hourly	Global	Temperature of air at 2m above the land surface	NetCDF, 9km

Indicator

No.	Indicator description	Temporal scope & resolution	Country coverage
1	Share of country's cropland area exposed to increasing heat stress	2000-2022, Annual	Global

Dimension I: Livestock exposure to flood risk

Description

The escalating global risk of flooding due to extreme weather events has become a significant threat to livestock production. Floods can cause severe stress, injuries, and even fatalities among animals. They also promote the spread of infectious diseases, contaminate drinking water sources, and disrupt normal feeding behaviours. Beyond these immediate impacts, flooding indirectly harms livestock by damaging animal facilities and farm infrastructure, disrupting feed production, and compromising feed storage (Crist, Mori and Smith, 2020[73]). This threat is particularly alarming, as projected global temperature increases of 1.5°C are expected to drive a rise in flooding events that exceed the capacity of current flood protection measures (IPCC, 2022[70]).

This indicator aims to measure changes in livestock exposure to flood risk resulting from shifts in livestock location. The FAO Global Livestock System data is used to determine the distribution of livestock species, including buffaloes, cattle, chickens, horses, goats, pigs, and sheep.[11] The different species of the livestock population have been standardised using the Livestock Unit (LSU), with one LSU referencing the weight of an adult dairy cow (Eurostat, 2024[74]). The global river flood hazard depth maps published by the European Commission's Joint Research Centre are used to identify cropland exposed to flood risk (Baugh et al., 2024[40]). 10-year return period floods over the 1979-2013 period are considered due to their significant impact and frequent occurrence, making them a common return reference period in several studies (IPCC, 2023[71]). The global river flood hazard depth maps are converted into binary data $f_c(x)$ indicating the presence or absence of flood risk in area x. The binary data is defined as:

$$f_c(x) = \begin{cases} 1 \text{ if the 10-year return period flood depth exceeds zero in area } x \text{ in country } c \\ 0 \text{ otherwise} \end{cases}$$

The total standardized number of livestock in country c exposed to flood risk at year t, denoted as $Flivest_{c,t}$.

$$Flivest_{c,t} = \sum_{x \,\in\, \text{livestock in } c \text{ at } t} f_c(x) * c(x),$$ with $c(x)$ the count of livestock unit (LSU) in area x.

The share of livestock exposed to flood risk in country c at time t ($Sh\_Flivest_{t,c}$) is calculated as:

$$Sh\_Flivest_{c,t} = \frac{Flivest_{c,t}}{Alivest_{c,t}},$$ with $Alivest_{c,t}$ the total population (LSU) of livestock in country c at time t.

Data

No.	Data	Source	Temporal scope & resolution	Country coverage	Description	Technical characteristics
1	Livestock distribution	Gridded Livestock of the World (GLW v4) (2018[42])	2010, 2015, 2020, Annual	Global	Count of livestock unit: buffaloes, cattle, chickens, horses, goats, pigs, and sheep	TIF, 5 arc minute resolution
2	Flood risk	Global river flood hazard maps (Baugh et al., 2024[40])	10-year return period based on 1979-2013	Global	Flood depth along the river network for seven different flood return periods (from 1-in-10-years to 1-in-500-years).	TIFF, 3 arc seconds resolution

Indicator

No.	Indicator description	Temporal scope & resolution	Country coverage
1	Share of country's livestock exposed to flood risk	2010, 2015, 2020, Annual	Global

Dimension I: Livestock exposure to heat stress

Description

Rising temperatures are intensifying heat stress in livestock, impacting productivity both indirectly through pastoral systems and directly by affecting livestock health and fertility (IPCC, 2022[1]). Warming and drying trends are degrading rangeland quality and undermining the economic viability of grazing systems. When temperatures exceed animals' comfort zones, their feed intake decreases by 3–5% for every additional degree, leading to reduced productivity and fertility (Nardone et al., 2006[59]). By 2100, over a billion cattle worldwide may experience heat stress (North et al., 2023[17]).

Rising temperatures will drive greater demand for adaptation measures in livestock, including changes in location, herd size, species, or enhanced physical measures such as shading and ventilation system. For instance, under the RCP 4.5 and RCP 8.5 scenarios, the proportion of land allocated to beef cows in the United States is projected to increase significantly, while the share for goats is expected to decline substantially (Wang and McCarl, 2021[75]).

This indicator aims to capture the livestock exposure to heat stress due to change in livestock location. The FAO Global Livestock System data is used to determine the distribution of livestock species, including buffaloes, cattle, chickens, horses, goats, pigs, and sheep,[11] and livestock population standardised based on their nutritional or feed requirement using the Livestock Unit (LSU) (Eurostat, 2024[74]). The heat stress threshold is defined by an average daily Temperature-Humidity Index (THI) above 69, based on studies showing that livestock productivity decreases above this THI value (Gisbert-Queral et al., 2021[45]; North et al., 2023[17]). $h_c(x)$ is a binary variable equal to 1 if area x of country c is classified as a heat stress risk area:

$$h_c(x) = \begin{cases} 1 \text{ if annual count of days with THI over 69 increased by 4 days between} \\ \qquad\qquad \text{1980-2010 and 2015-2020 in area } x \; of \text{ country } c, \\ 0 \text{ otherwise} \end{cases}$$

The total standardized number of livestock in country c exposed to heat stress risk at year t, denoted as $Hlivest_{c,t}$.

$$Hlivest_{c,t} = \textstyle\sum_{x \in \text{livestock in } c \; at \; t} h_c(x) * a(x), \text{ with } a(x) \text{ the count of livestock unit in area } x.$$

The share of livestock exposed to heat stress in country c at time t ($Sh\_Hlivest_{c,t}$) is calculated as:

$$Sh\_Hlivest_{c,t} = \frac{Hlivest_{c,t}}{Alivest_{c,t}}, \text{ with } Alivest_{c,t} \text{ the total population (LSU) of livestock in country } c \text{ at time } t.$$

Data

No.	Data	Source	Temporal scope & resolution	Country coverage	Description	Technical characteristics
1	Livestock distribution	Gridded Livestock of the World (GLW v4) (2018[42])	2010, 2015, 2020, Annual	Global	Count of livestock (buffaloes, cattle, chickens, horses, goats, pigs and sheep)	TIF, 5 arc minute resolution
2	Temperature	Copernicus ERA5 land (2024[43])	1950-present, daily	Global	Temperature and dewpoint temperature of air at 2m above the land surface	NetCDF, 9km

Indicator

No.	Indicator description	Temporal scope & resolution	Country coverage
1	Share of country's livestock exposed to increasing heat stress	2010, 2015, 2020, Annual	Global

Dimension II: Crop suitability

Description

With projections pointing to more variability in rainfall and a rise in temperatures, the suitability of crops for each region will shift accordingly. Without adaptation, current global crop production will increasingly become unsuitable, threatening food availability and posing increased risk of hunger (Kummu et al., 2021[76]).

To maintain or improve production efficiency, farmers can select crops better suited to the evolving climate conditions. Especially in vulnerable regions facing drastic change in extreme weather events such as Southern Europe, short-term adaptation strategies may involve switching to resilient crop species or those with longer growth cycles to better withstand changing environmental conditions (Olesen et al., 2011[77]).

This indicator aims to measure the change in average country level crop suitability to environmental conditions. The suitability of agricultural production to local climate conditions is assessed by combining the FAO Global Agro-Ecological Zones (GAEZ) crop suitability index (FAO and IIASA, 2022[49]), which rates each area from not suitable to very suitable for various type of crops, with the Spatial Production Allocation Model (SPAM) providing gridded data on crop types for the years 2000, 2005, 2010 and 2020 (You et al., 2014[50]). This indicator represents the proportion of country c total agricultural area $(Sh\_suit_{c,t})$ where the crops grown are classified from moderately (Suitability Index > 2500) to very suitable to local climatic conditions:

$$Sh\_suit_{c,t} = \frac{Suit\_crop_{c,t}}{Acrop_{c,t}}$$

where $Suit\_crop_{c,t}$ represents the total area of cropland cultivated in suitable areas in country c at time t, and $Acrop_{t,c}$ is the total cropland area in country c at time t.

Data

No.	Data	Source	Temporal scope & resolution	Country coverage	Description	Technical characteristics
1	Crop physical area	SPAM	2000, 2005, 2010, 2020, three-year average, including the year before and the year after	Global	Crop-growing area for 30 different crop types	Tiff, 30 arc-second resolution
2	Suitability Index	GAEZ v4	Based on 1981-2010 period, with no recurrence	Global	Suitability Index based on thermal, moisture, and soil requirements for 30 different crop types	Tiff, 5 arc-minute resolution

Indicators

No.	Indicator description	Temporal scope & resolution	Country coverage
1	Share of country's total agricultural area where the crops grown are suitable to local climate conditions.	2000, 2005, 2010, 2020, three-year average, including the year before and the year after	Global

Dimension II: Crop diversity

Description

The reduction in crop species diversity contributing to global food supplies is seen as a potential threat to global food security and resilience (Khoury et al., 2014[78]). Conventional monocropping has demonstrated lower productivity and resilience compared to more diverse cropping systems (Mijatović et al., 2013[79]). Monocropping also limits social benefits, ecosystems services, pest control and nutrient use efficiency (Gebru, 2015[80]).

Increasing crop diversity has been proven to enhance climate resilience (Schaak et al., 2023[47]; Li et al., 2009[81]). For example, corn yields in highly diverse systems (systems incorporating more species and crop rotation) were more than twice higher than in continuous monoculture (Smith, Gross and Robertson, 2008[82]), and combinations like potatoes with maize or wheat with broad beans increased yields by 33.2% to 84.7% (Li et al., 2009[81]).

This indicator aims to measure the evolution of country level crop production diversity. The Shannon index, the most widely used metrics to assess the diversity of countries' agricultural (or broader economic) production (Schaak et al., 2023[47]), quantifies crop diversity based on the number of different crops grown in a country and their proportional share of total country's cultivated land, using FAO primary crops production data covering 151 crop types (FAO, 2024[48]). Higher value of the Shannon index denotes higher diversity. It is defined as:

$$Diversity_{c,t} = - \sum_{\substack{j \in \text{crop types} \\ \text{grown in } c\ at\ t}} \alpha_{j,c,t} * \ln \alpha_{j,c,t}$$

where α_{jc} is the share of harvested cropland area occupied by crop type *j* in total harvested cropland area of country c.

Data

No.	Data	Source	Temporal scope & resolution	Country coverage	Description	Technical characteristics
1	Harvested area by crop type	Crops and livestock products (FAO, 2024[48])	1961-2021, annual	Global	Country level annual harvested area (ha) per crop type	Excel

Indicators

No.	Indicator description	Temporal scope & resolution	Country coverage
1	Crop diversity measured by the Shannon index	1961-2021, annual	Global

Dimension II: Livestock production diversity

Description

Similar to crop systems, increasing livestock diversity can enhance countries' resilience to extreme weather events. While some species are inherently adapted to specific climatic conditions (e.g. camels in arid environments), broader diversification across species and breeds enhances the sector's capacity to withstand climate-related shocks and reduces systemic vulnerabilities. First, livestock species vary in their sensitivity to climatic stressors. For example, dairy cattle are more sensitive to heat stress than beef cattle (Godde et al., 2021[83]). In addition, occurrence and spread of animal diseases are projected to intensify in the future, particularly in uniform systems. Greater species and genetic diversity can act as a buffer against such risks, reducing the speed and scale of disease transmission and improving agricultural system resilience (FAO, 2015[84]). Third, livestock species differ significantly in the quantity and quality of feed and water they need. Integrating species such as goats and sheep, which are more drought-tolerant and less reliant on high-quality forage, can ease pressure on specific resources but also support crop diversification (IPCC, 2022[1]).

This indicator aims to measure the evolution of country level livestock production diversity. The Shannon index, the most widely used metrics to assess the diversity of countries' agricultural (or broader economic) production (Schaak et al., 2023[47]), quantifies livestock diversity based on the number of different livestock species (for milk and meat) grown in a country and their proportional share of total country's livestock unit, using FAO primary livestock production covering 15 livestock species, whose 5 are bred for both their meat and milk (buffalo, camel, cattle, sheep and goat) (FAO, 2024[48]). Higher value of the Shannon index denotes higher diversity. It is defined as:

$$Diversity_{c,t} = -\sum_{\substack{j \in \text{livestock species} \\ \text{in } c \text{ } at \text{ } t}} \alpha_{j,c,t} * \ln \alpha_{j,c,t}$$

where α_{jc} is the share of livestock unit of livestock type j in total livestock unit of country c. Livestock unit is computed as the number of animals of a given specie times the livestock unit coefficients of this specie (Eurostat, 2024[74]).

Data

No.	Data	Source	Temporal scope & resolution	Country coverage	Description	Technical characteristics
1	Number of producing animals	Crops and livestock products (FAO, 2024[48])	1961-2021, annual	Global	Annual number of producing animals at the country level, by livestock species and type of production (meat or milk).	Excel

Indicators

No.	Indicator description	Temporal scope & resolution	Country coverage
1	Livestock diversity measured by the Shannon index	1961-2021, annual	Global

Dimension II: Agricultural water use and water footprint

Description

Extreme weather events disrupt the global water cycle, increasing soil drought risk and water demand while reducing freshwater availability, posing significant challenges to agricultural water management. This threatens farmers' ability to grow water-intensive crops and manage rising drought risks. The IPCC estimates that drought-driven yield losses by 2071–2100 (RCP8.5) could reach 9–12% for wheat, 5.6–6.3% for maize, 18.1–19.4% for rice, and 15.1–16.1% for soybeans (IPCC, 2022[1]). Meanwhile, global water use for agriculture has doubled over the past 50 years (Otto and Schleifer, 2020[85]).

Better management of water resources in the agricultural sector is crucial to cope with scarer water resources. Reducing the water footprint of the agricultural sector is thus a priority for many OECD countries. Various adaptation solutions, such as more efficient irrigation or changes in crop species, aim to reduce water consumption in agriculture. Agricultural water policies play a key role in guiding farmers adoption of these solutions effectively (OECD, 2017[86]).

Two indicators are built to monitor the water intensity of the agricultural production. The first indicator $W\_int\_irrig_{c,t}$ represents the quantity of water withdrawal for irrigation per unit of cropland area in country c at time t. It is defined as:

$$W\_int\_irrig_{c,t} = \frac{Wirrig_{c,t}}{Acrop_{c,t}}$$

where $Wirrig_{c,t}$ represents the quantity of water abstracted per year for irrigation in country c, and $Acrop_{t,c}$ the total cropland area in country c at time t. $Wirrig_{c,t}$ is given by OECD freshwater abstraction for irrigation data (OECD, 2024[54]) if it covers at least 3 years for a given country for both the periods 2000-2005 and 2015-2020. Otherwise, FAO AQUASTAT data on irrigation are used following the same criteria (FAO, 2021[53]). If the coverage of OECD and AQUASTAT irrigation data is insufficient (more than 3 years missing for any of the two period for both AQUASTAT and OECD), the ratio of water use for irrigation over total water withdrawal for agriculture is computed for available years using FAO AQUASTAT data, and water use for irrigation is computed as this ratio times total water withdrawal for agriculture from AQUASTAT (FAO, 2021[53]).

The second indicator $Wfootprint_{c,t}$, which represents the total water footprint (water consumed) of agricultural production in country c at year t, is defined as:

$$Wfootprint_{c,t} = \sum_{j \in \text{crop types grown in } c\ at\ t} wf\_tot_{j,c,t} * prod\_tot_{j,c,t}$$

where $wf\_tot_{j,c,t}$ is the total water footprint (m3 per ton), as defined in Mialyk et al. (2024[55]), and $prod\_tot_{j,c,t}$ the total production (in ton) of crop type j in country c at time t.

Data

Data	Source	Temporal scope & resolution	Country coverage	Description	Technical characteristics
Water use for irrigation	Freshwater-Abstractions (OECD, 2024[54]) and AQUASTAT (FAO, 2021[53])	2000-2022, Annual	Global	Water withdrawal for irrigation (m^3)	Excel
Cropland area	AQUASTAT (FAO, 2021[53])	2000-2022, Annual	Global	Arable land +permanent crops (1000ha)	Excel
Water footprint	(Mialyk et al., 2024[55])	1990–2019, Annual	Global	Total water footprint by crop type ($m^3.ton^{-1}$)	Excel
Crop production	(Mialyk et al., 2024[55])	1990–2019, Annual	Global	Crop production by crop type (ton)	Excel

Indicators

No.	Indicator description	Temporal scope & resolution	Country coverage
1	Water use intensity: Annual country’s water withdrawal for irrigation by unit of cropland area ($m^3.ha^{-1}$)	2000-2022, Annual	Global
2	Water footprint: Annual country’s agricultural production water footprint (m^3)	1990–2019, Annual	Global

Dimension II: Development of irrigation

Description

Drought, by reducing soil moisture, is recognized as a major factor negatively impacting both the quantity and quality of the agricultural production. Drought-related yield losses have affected approximately 75% of the global cropland area from 1983 to 2009, with an upward trend in recent years (IPCC, 2022[1]). According to the IPCC, overall drought-driven yield loss is estimated to increase by 9–12% (wheat), 5.6–6.3% (maize), 18.1–19.4% (rice) and 15.1–16.1% (soybean) by 2071–2100, relative to 1961–2016 (RCP8.5) (IPCC, 2022[1]). Moreover, water stress induced by droughts reduces metabolic processes of crops responsible for producing soluble sugars, proteins, starch, and lipids, and thus impact crops quality (Stagnari, Galieni and Pisante, 2016[67]).

The growing risk of drought and the value-added of irrigated crops can encourage the adoption of irrigation to sustain agricultural productivity. Irrigation is an effective strategy for mitigating the impact of water stress on crop yields (IPCC, 2022[1]). Many countries, such as Spain or Austria, make the development of more efficient irrigation systems key components of their adaptation strategy for the agricultural sector (BMK, 2024[27]; Gobierno de España, 2020[30]).

This indicator monitors irrigation capacity as the area of country's cropland equipped with irrigation using FAO AQUASTAT data.

Data

No.	Data	Source	Temporal scope & resolution	Country coverage	Description	Technical characteristics
1	Irrigation equipped land	AQUASTAT (FAO, 2021[53])	2000-2022, Annual	Global	Land area equipped with irrigation infrastructure (ha). The equipment does not have to be used during the reference year.	Excel

Indicators

No.	Indicator description	Temporal scope & resolution	Country coverage
1	Country's annual irrigation capacity measured as the area of cropland equipped for irrigation	2000-2021, Annual	Global

Dimension III: Fluctuations in crop, meat, and milk yields

Description

Change in inter-annual and seasonal meteorological conditions poses a significant threat to the sustainability of agricultural production. Since meteorological conditions during the growing season are key drivers of crop yields, shifts in these conditions jeopardize the resilience of agricultural systems. For example, evidence shows that climate fluctuations account for one-quarter of yield variation in the United States Great Plains between 1968 and 2013, with the remaining variation influenced by factors such as agricultural practices, crop selection, and irrigation, key components of climate adaptation (Kukal and Irmak, 2018[87]). Similarly, livestock diary and meet production is highly sensitive to climate conditions (Nardone et al., 2006[59]; Gisbert-Queral et al., 2021[45]; North et al., 2023[60]). The volatility of agricultural production threatens global food supply, but also farmers' revenue stability and their ability to invest in and adapt to changing climate conditions. Consequently, addressing the challenges posed by climate variability is essential to safeguarding food production and the economic viability of the agricultural sector.

Monitoring annual crop, meat and milk yield variations offers valuable insights into the resilience of the agricultural production to climate extremes. Since the production is shaped by both climate conditions and agricultural practices, year-to-year fluctuations serve as indicators of the agricultural sector's ability to absorb and recover from such shocks. Lower yield variability signifies a greater capacity of the agricultural sector to mitigate the impacts of climate disruptions.

This indicator assesses average crop, meat and milk yield fluctuation across all crops grown and animals breed in the country to inform agricultural production resilience to climate extremes. The annual value of the indicators represents the weighted average fluctuation in country's crop, milk and meat yields. The crop yield fluctuation indicator is calculated by summing, across all crops grown in the country, the annual yield variation for each crop (measured as the difference between its annual yield and the average yield of the previous six years, expressed as a percentage of that six-year average) multiplied by the crop's share of the country's total harvested area. The yield fluctuation indicator $Yield\_Crop\_Fluct_{c,t,p}$ is inspired by the "LW-I-2: Yield fluctuation indicator" used by Germany (Umwelt Bundesamt, 2023[61]), and is defined as the weighted percentage change in yield between average yield in country *c* at year *t* and average yields in this country over the previous 6 years:

$$Yield\_Crop\_Fluct_{c,t} = \sum_{j \in \text{crop types grown in } c \text{ at } t} \frac{Harv_{c,j,t}}{Tot\_Harv_{c,t}} * \frac{Yield_{c,t,j} - \frac{1}{6}\sum_{k=t-6}^{t-1} Yield_{c,k,j}}{\frac{1}{6}\sum_{k=t-6}^{t-1} Yield_{c,k,j}}$$

where $Yield_{c,t,p}$ is the average national yield of crop type *j* at year *t* for country *c*, $Harv_{c,j,t}$ the harvested area of crop *j*, at year *t* in country *c*, and $Tot\_Harv_{c,t}$ the total harvested area in country *c* at year *t*.

Similarly, fluctuations in animal production (meat or milk) yields $Yield\_livestock\_Fluct_{c,t}$ are computed as:

$$Yield\_livestock\_Fluct_{c,t} = \sum_{j \in \text{livestock species reared in } c \text{ at } t} \frac{Animals_{c,j,t}}{Tot\_Animals_{c,t}} * \frac{Yield_{c,t,j} - \frac{1}{6}\sum_{k=t-6}^{t-1} Yield_{c,k,j}}{\frac{1}{6}\sum_{k=t-6}^{t-1} Yield_{c,k,j}}$$

where $Yield_{c,t,j}$ is the average national meat or milk yield of specie *j* at year *t* for country *c*, $Animals_{c,j,t}$ the number of producing animals of species *j*, at year *t* in country *c*, and $Tot\_Animals_{c,t}$ the total number of animals reared in country *c* at year *t*.

Data

Data	Source	Temporal scope & resolution	Country coverage	Description	Technical characteristics
Crop production	Crops and livestock products (FAO, 2024[48])	1961-2021, annual	Global	Country level annual yields and total harvested area per crop type	Excel
Meat and milk production	Crops and livestock products (FAO, 2024[48])	1961-2021, annual	Global	Country level annual yields and total number of producing animal per crop type	Excel

Indicators

Indicator description	Temporal scope & resolution	Country coverage
Weighted percentage deviation of annual crop, milk or meat yields from the average yield over the previous 6 years	1961-2021, Annual	Global

Dimension IV: Innovation in agricultural technologies

Description

Innovation and the creation of knowledge and tools, including the development of new technologies, is necessary to cope with the new challenges and opportunities offered by a changing climate (Fankhauser, 2017[88]; Touboul et al., 2023[89]). Highlighting the importance of technology development for adaptation in food production, the words "technology", "technological" and "innovation" appear more than 120 times in the fifth chapter of the AR6 Working Group IPCC report dedicated to "Food, Fibre and Other Ecosystem Products" (IPCC, 2022[1]).

Tracking patenting activity is a widely used indicator to measure technological innovation and the creation of knowledge. Patent constitutes a way to protect new technologies and processes. It represents the output of public and private sector effort in innovation (e.g. R&D spending, training and hiring of researchers). Patents contain information on the inventor of the technology, its nationality, and a detailed description of the technology to be protected, allowing for a refine analysis of innovation in very specific sectors. Thus, the number of patents invented in a country has been widely used to describe the geography and dynamic of innovation in adaptation technologies (Touboul, 2021[64]; Miao and Popp, 2014[90]).

This indicator measures the specialisation of country invention in agricultural adaptation technologies. Country's specific efforts in the development of adaptation related knowledge can be assessed by analysing the specialisation of a country in adaptation technologies $Spe\_Adapt_{t,c}$, measured as the share of adaptation related patents in all patents:

$$Spe\_Adapt_{t,c} = \frac{Inv\_Adapt\_Agri_{t,c}}{Inv\_Agri_{t,c}}$$

where $Inv\_Adapt\_Agri_{t,c}$ represents the number of agricultural adaptation patents invented by country c at year t and $Inv\_Agri_{t,c}$ the number of all agricultural related patents invented by country c at year t. Patents invented in country c at year t are patents for which the nationality of the inventor is country c, and the first priority patent of the patent family (Docdb) has been filed at year t. The CPC classification is used to identify the purpose of the technology. 'Agricultural adaptation" technologies are patents in the category "Adaptation technologies in agriculture, forestry, livestock or agroalimentary production" (CPC code Y02A40), from which are excluded 'fisheries management' and 'food processing' technologies. "All agricultural" technologies are identified with the CPC code "A01".

Data

Data	Source	Temporal scope & resolution	Country coverage	Description	Technical characteristics
Patent	OECD Science Technology and Innovation (STI) Micro-data Lab's Intellectual Property Database (2024[63])	1960-2023	169 patent offices	The World Patent Statistical Database (PATSTAT) is a patent database covering almost all patents filed worldwide maintained by the European Patent Office (EPO)	Individual patents information, including the earliest year of filling, the name and nationality of the inventor and detailed information on the protected technology

Indicators

Indicator description	Temporal scope & resolution	Country coverage
Percentage of agricultural adaptation patents invented in all agricultural patents. ‘Agricultural adaptation” patents belong to the category “Adaptation technologies in agriculture, forestry, livestock or agroalimentary production” (CPC code Y02A40), excluding ‘fisheries management’ and ‘food processing’ technologies. “All agricultural” patents are identified with the CPC code “A01”.	1995-2020, annual	Global

Dimension IV: Agriculture in National Adaptation Plans or Strategies

Description

Adapting the agricultural sector to extreme weather events requires coordination and prioritisation of actions over time, sectors and regions. Adaptation relies on a wide range of actions that often require collaboration between multiple stakeholders and across localities (OECD, 2023[26]). This is particularly important in the agricultural sector, where reliance on shared natural resources demands careful management to ensure their sustainability. Given that adaptation actions demand substantial resources, ranging from funding to skilled labour and often specialized knowledge, prioritization becomes crucial due to the limited availability of these resources. Strategic adaptation planning is therefore essential to prioritize actions based on available resources and align them with national adaptation objectives.

National Adaptation Plans (NAPs) or Strategies (NAS) serve as essential reference documents for OECD countries to outline and communicate their national adaptation goals and priorities. To date, all OECD countries have published at least one NAP or NAS, establishing a foundation for nationally coordinated and coherent adaptation actions. These documents offer a cross-sectoral, country-wide perspective on each nation's adaptation strategy. While the format and content vary significantly between countries, all NAPs and NAS identify priority sectors and actions for adaptation, along with overarching adaptation objectives. Some documents take this further, setting quantified, time-bound targets, identifying necessary resources, and designating entities responsible for implementing adaptation actions.

This indicator reviews the extent to which the agricultural sector is integrated into national adaptation plans. An index ranging from 0 to 10 is built depending on the content of the document regarding the agricultural sector, based on criteria described in the table below.

Score	Criteria
NA	No NAP/NAS or sectoral adaptation plan
0	Agriculture is not mentioned in the NAP/NAS and no sectoral adaptation plan exists
1	Agriculture is mentioned in the NAP/NAS or a sectoral adaptation plan exists
2	Specific objective(s) for agriculture are detailed in the document
3 - 10	One additional point for each of the below criteria meet: - Adaptation options and actions are identified - Objective(s) or action(s) are timebound[a] - Objective(s) or action(s) are measurable[b] - Objective(s) and action(s) are based on a climate risk assessment[c] - Available resources are identified and/or dedicated (funding, but also capacity building)[d] - Identification of entities responsible for taking action/fulfilling the objective(s)[e] - Mechanisms or entities are identified to ensure cross sectoral and multi-level coordination[f] - Monitoring and evaluation processes are identified[g]

Note: The acronyms "NAP" stands for National Adaptation Plan, and "NAS" for National Adaptation Strategy. For the section "3-10", compliance with one criterion is assigned one additional point. 0.5 points can be attributed if the criterion is not fully met: a) if only some objectives are timebound or if the deadlines are defined in qualitative terms only (e.g. short term, medium term, long term are awarded for criteria; b) if only some of the objectives and actions are measurable; c) if the climate risk assessment exist but does not detail risks or impacts for agriculture specifically; d) if resources that have already been allocated are mentioned, and/or if funding needs are identified without specifying the sources (and vice versa); e) if responsibilities are defined for a limited number of stakeholders (e.g. some national ministries only) or for some objective(s) or action(s) only; f) if the necessity for cross-sectoral or multi-level coordination is acknowledge in the NAP but no coordination body nor cross-sectoral objective(s) are defined; g) if the plan contains information or a section on monitoring, reporting or evaluation but does not fully qualify the reporting/monitoring system, or the system is detailed but not in place yet.

Data

Data	Source	Temporal scope & resolution	Country coverage	Description	Technical characteristics
National Adaptation Plans or Strategies	Country's NAPs or NAS	2005-2022, periodic (depending on countries)	OECD countries	National Adaptation Plans, Strategies, or sectoral adaptation plans released by OECD countries	PDF documents listed in Table A B.4, translated in English with Google Translate if need be

Indicators

Indicator description	Temporal scope & resolution	Country coverage
Index ranging from 0 to 10 based on the criteria detailed in the table above	Country specific	OECD

Dimension IV: Implementation of adaptation policies

Description

While farmers may act autonomously to change in local climatic conditions to reap the private benefits of adaptation action, it is unlikely that autonomous adaptation will lead to a sufficient or socially optimal level of resilience of the agricultural sector (IPCC, 2022[1]). Lack of information, of technical and financial capacities and of economic incentives, as well as inappropriate institutional and regulatory framework may undermine actions for adaptation or even lead to maladaptation (OECD, 2023[8]). In addition, farmers may rely on public or collective infrastructure (e.g. water network), which also needs to be adapted to meet the needs of agriculture. Finally, large-scale adaptation may require a major transformation that goes beyond individual farm actions, requiring coordinated and prioritized efforts to effectively address resource limitations.

Implementation of adaptation policies is thus key to incentivize adaptation in the agricultural sector. Public intervention can serve multiple purposes, such as leveraging institutional and regulatory barriers for private adaptation, generating and sharing knowledge, favoring coordinated actions or correcting for externalities (Ignaciuk, 2015[11]). Examples of adaptation policies include the creation of funding mechanisms, implementation of laws, use of economic instruments or the creation of coordination and governance bodies.

This indicator measures the number of distinct national adaptation policies and programmes introduced in the agricultural sector, reflecting countries' efforts to create an enabling environment for climate adaptation. It builds on an analysis of 54 countries' submissions to the UNFCCC (including all OECD countries) from the 2023 OECD Agricultural Policy and Monitoring report (OECD, 2023[8]). By examining over 600 identified adaptation measures and programmes, the indicator quantifies the scope of policy actions aimed at fostering resilience. It also addresses aspects of the enabling environment that overlap with other indicators, such as planning and knowledge creation.

Data

Data	Source	Temporal scope & resolution	Country coverage	Description	Technical characteristics
Adaptation policies and programmes	OECD Agricultural Policy Monitoring & Evaluation 2023 (2023[8]).	1994-2022, periodic	OECD countries	The OECD reviewed National Communications, Nationally Determined Contributions (NDCs) and Adaptation Communications submitted by OECD countries to the UNFCCC to extract and categorized agricultural measures and programmes related to adaptation.	Excel file with number of policies by countries

Indicators

Indicator description	Temporal scope & resolution	Country coverage
Number of adaptation policies and programmes mentioned in National Communication documents submitted to the UNFCCC per country	1994-2020	54 countries[12]

Annex B. Country scores

I. Agricultural Exposure to Climate Hazards

Table A B.1. Country’s score for indicators of dimension I: Agricultural Exposure to Climate Hazards

Change in the share of countries’ cropland area and livestock (Livestock Unit) exposed to drought, flood and heat stress due to change in production location between the periods 2000-2005 and 2015-2020 (cropland) and the years 2010 and 2020 (livestock).

Country	Cropland Drought		Cropland Flood		Cropland Heat Stress		Livestock Flood		Livestock Heat Stress	
	Growth (%)	Difference (%p)	Growth (%)	Difference (%p)	Growth (%)	Difference (%p)	Growth (%)	Difference (%p)	Growth (%)	Difference (%p)
Australia	-0.01%	-0.01	0.40%	0.04	0.28%	0.21	1.26%	0.88	-4.71%	-4.17
Austria	-0.64%	-0.21	-1.28%	-0.06	-1.72%	-0.66	-0.81%	-0.61	-1.09%	-0.87
Belgium	-0.07%	-0.05	-0.56%	-0.02	2.19%	0.00	-4.47%	-2.46	-21.79%	-21.46
Canada	-0.43%	-0.30	-0.34%	-0.01	1.04%	0.00	-3.14%	-2.22	-10.42%	-4.09
Chile	-1.33%	-0.77	0.35%	0.01	-0.55%	-0.16	4.22%	3.18	23.45%	6.51
Colombia	-1.64%	-0.23	-0.55%	-0.08	1.46%	1.08	0.75%	0.58	5.46%	0.81
Costa Rica	8.35%	1.44	-0.76%	-0.06	10.81%	2.18	0.36%	0.24	-0.03%	-0.01
Czechia	0.04%	0.01	-0.40%	-0.01	-0.56%	-0.12	-2.61%	-1.57	0.44%	0.43
Denmark	-0.88%	-0.24	-0.32%	0.00	-	0.00	0.12%	0.03	869.26%	1.66
Estonia	1.74%	0.12	-2.70%	-0.06	-	0.00	-0.60%	-0.27	0.00%	0.00
Finland	5.16%	0.01	0.69%	0.02	-	0.00	0.45%	0.30	0.00%	0.00
France	0.06%	0.05	-0.56%	-0.02	-0.16%	-0.11	2.11%	1.24	-26.47%	-20.17
Germany	-0.51%	-0.12	-0.05%	0.00	-0.41%	-0.05	-0.52%	-0.34	-1.81%	-1.69
Greece	0.20%	0.15	2.03%	0.10	0.40%	0.29	-1.99%	-1.07	0.26%	0.23
Hungary	0.24%	0.09	0.10%	0.02	0.00%	0.00	-1.21%	-0.93	0.00%	0.00
Iceland	-	-	-	-	-	-	11.01%	4.46	0.00%	0.00
Ireland	0.00%	0.00	-0.58%	-0.01	-	0.00	0.35%	0.21	0.00%	0.00
Israel	0.01%	0.01	0.80%	0.01	0.03%	0.03	3.82%	2.52	3.25%	2.69
Italy	0.18%	0.12	0.10%	0.01	0.11%	0.09	1.16%	0.93	0.26%	0.24
Japan	0.00%	0.00	-7.73%	-0.49	-5.88%	-2.28	-0.63%	-0.40	-36.17%	-28.08
Korea	-3.33%	-0.04	-5.48%	-0.21	-1.36%	-1.13	-2.15%	-1.37	-80.84%	-63.92
Latvia	-	0.00	-0.80%	-0.02	-	0.00	1.54%	0.96	-92.17%	-15.37
Lithuania	-	0.00	0.25%	0.00	-	0.00	3.61%	2.12	-31.34%	-27.66
Luxembourg	0.10%	0.09	0.70%	0.01	0.64%	0.04	8.14%	3.69	0.00%	0.00
Mexico	0.06%	0.05	-0.48%	-0.06	0.55%	0.37	-0.01%	-0.01	0.97%	0.70
Netherlands	-0.08%	-0.05	-1.10%	-0.10	-	0.00	-3.43%	-2.35	-6.92%	-6.66
New Zealand	2.79%	1.38	3.80%	0.10	-	0.00	3.44%	2.35	26.40%	5.67
Norway	-6.45%	-1.10	4.56%	0.08	-	0.00	4.69%	2.11	0.00%	0.00
Poland	0.06%	0.03	-0.09%	0.00	0.51%	0.05	-0.63%	-0.40	0.03%	0.03
Portugal	0.06%	0.06	-0.23%	-0.01	-1.44%	-1.11	-0.52%	-0.32	-0.25%	-0.20
Slovakia	0.30%	0.14	-0.11%	-0.01	-0.13%	-0.08	-0.17%	-0.13	1.66%	1.55
Slovenia	10.12%	0.04	-2.71%	-0.08	-3.26%	-0.59	-1.75%	-1.38	0.22%	0.21
Spain	0.04%	0.04	-0.43%	-0.01	-0.06%	-0.06	0.82%	0.55	-3.76%	-3.34
Sweden	-8.67%	-1.53	1.02%	0.03	-	0.00	-0.84%	-0.55	34.00%	2.49
Switzerland	-0.16%	-0.01	-0.25%	-0.02	-0.58%	-0.01	-0.38%	-0.30	1.05%	0.81
Türkiye	0.06%	0.06	1.18%	0.03	0.33%	0.25	-1.38%	-0.96	0.08%	0.06
United Kingdom	-1.01%	-0.13	0.93%	0.03	-	0.00	0.80%	0.42	-77.08%	-1.91
United States	-0.45%	-0.23	-0.86%	-0.06	-0.73%	-0.25	0.27%	0.19	-13.54%	-12.82

Note: The "Difference" column shows the change in the average annual country’s share of total cropland area or total Livestock Unit exposure to the hazard. The difference is computed as the average annual value over the period 2015–2020 minus the value for 2000–2005 for cropland, and the value for 2020 minus the value for 2010 for livestock. The "Growth" column represents the ratio (expressed as a percentage) between the average annual country’s share of total cropland area exposed to the hazard in 2015–2020 and that in 2000–2005, or the share of total livestock unit exposure to the hazard in 2020 and that in 2010. It is computed as the value in the “Difference” column divided by the absolute value of the average annual indicator value for the period 2000-2005 (cropland) or its value in 2010 (livestock) No result (i.e., "-") for growth and a value of 0 for the difference indicates that the production is not exposed to this given hazard in the country. No results are available for Iceland since no cropland cover is detected using Copernicus global land cover data.

Source: Authors’ own, using: Cropland: OECD processed Copernicus Global Land Cover data (Copernicus Climate Change Service, 2019[38]); Livestock: Gridded Livestock of the World GLW v4 (Gilbert et al., 2018[42]); Drought: Soil moisture gridded data (Copernicus Climate Change Service, 2018[39]); Heat stress: ERA5-Land hourly data (Muñoz Sabater, J., 2019[41]) and ERA5-Land post-processed daily statistics (Copernicus Climate Change Service, 2024[43]); Flood: Global river flood hazard maps (Baugh et al., 2024[40]).

II. Resilient Agricultural Practices Reducing Vulnerability

Table A B.2. Country's score for indicators of dimension II: Resilient Agricultural Practices Reducing Vulnerability

Change in the share of countries' cropland area suitable to local climate condition, the Shannon crop production diversity index, the total water withdrawal for irrigation, the total water footprint of agricultural production and the area equipped for irrigation between the periods 2000-2005 and 2015-2020

Country	Crop Suitability		Crop Diversity		Livestock Diversity		Water Use for Irrigation		Water Footprint		Irrigation Capacity	
	Growth	Difference (%p)	Growth	Difference (index)	Growth	Difference (index)	Growth	Difference (10^9m3/ha)	Growth	Difference (10^9m3/yr)	Growth*	Difference* (%p)
Australia	-7.43%	-5.58	2.95%	0.05	0.65%	0.01	-73.35%	-0.28	-12.64%	-308.61	0.35%	-1.96
Austria	3.38%	3.22	0.57%	0.01	0.83%	0.01	19.78%	0.01	2.11%	73.58	0.83%	0.31
Belgium	1.05%	1.04	-1.50%	-0.04	-0.38%	0.00	-	-	-0.76%	-27.35	-4.61%	-0.17
Canada	2.68%	2.52	-3.46%	-0.07	-1.52%	-0.02	-14.34%	-0.01	2.59%	74.71	2.39%	0.21
Chile	7.24%	6.27	11.10%	0.31	-10.0%	-0.15	-	-	5.35%	206.21	0.91%	6.65
Colombia	-1.76%	-1.50	2.26%	0.06	2.85%	0.04	275.86%	2.85	6.10%	406.29	14.72%	1.30
Costa Rica	0.97%	0.93	-0.79%	-0.02	-1.53%	-0.02	-	-	6.84%	478.29	49.34%	5.70
Czechia	0.28%	0.27	-8.10%	-0.17	-0.45%	-0.01	135.38%	0.01	-7.72%	-240.17	-7.16%	0.08
Denmark	0.68%	0.67	8.43%	0.13	-2.31%	-0.01	29.12%	0.02	-6.94%	-198.09	-37.11%	-7.81
Estonia	1.54%	1.52	-3.82%	-0.07	-18.12%	-0.22	-89.77%	0.00	-5.01%	-133.87	77.22%	0.13
Finland	7.54%	7.01	4.95%	0.08	-0.28%	0.00	996.16%	0.18	-6.55%	-150.44	-35.54%	-1.53
France	1.45%	1.41	0.38%	0.01	-5.66%	-0.10	-46.31%	-0.12	-4.66%	-160.47	3.46%	0.66
Germany	0.66%	0.66	-2.80%	-0.06	-10.88%	-0.12	182.13%	0.02	1.80%	65.74	35.56%	1.52
Greece	31.69%	21.62	5.46%	0.13	-6.14%	-0.12	9.19%	0.21	4.46%	175.53	21.89%	17.20
Hungary	0.11%	0.11	-3.22%	-0.07	-7.90%	-0.12	6.91%	0.00	1.80%	68.17	0.40%	0.35
Iceland	-	-	89.35%	0.32	1.49%	0.02	-	0	39.02%	10.42	-	-
Ireland	0.08%	0.08	-11.59%	-0.17	-4.20%	-0.07	-73.96%	0.00	0.39%	9.23	-	-
Israel	-4.81%	-4.31	-1.59%	-0.05	-8.62%	-0.12	-	-	1.73%	64.03	38.00%	13.47
Italy	9.55%	7.27	0.03%	0.00	-3.13%	-0.06	14.18%	0.22	4.96%	201.02	4.20%	7.68
Japan	-2.01%	-1.65	-2.55%	-0.06	-4.13%	-0.04	2.66%	0.31	5.12%	199.74	-6.65%	-0.11
Korea	-18.0%	-16.57	-22.42%	-0.48	-0.54%	-0.01	1.20%	0.08	5.61%	218.62	-18.27%	-2.95
Latvia	0.29%	0.28	-10.97%	-0.24	3.90%	0.05	26.27%	0.00	-4.50%	-131.74	-23.85%	-0.04
Lithuania	-0.95%	-0.95	-8.57%	-0.17	1.47%	0.02	-53.94%	0.00	3.72%	119.52	-20.84%	-0.15
Luxembourg	0.50%	0.49	5.69%	0.13	-8.50%	-0.09	-18.16%	0.00	0.59%	16.93	-	-
Mexico	2.22%	1.76	-1.46%	-0.03	-4.29%	-0.06	19.63%	0.42	3.64%	182.18	10.80%	5.63
Netherlands	2.10%	2.05	-1.24%	-0.04	-1.20%	-0.01	102.45%	0.08	8.16%	291.16	32.26%	13.22
New Zealand	8.48%	7.54	4.49%	0.07	0.05%	0.00	8.72%	0.38	4.31%	125.85	46.07%	19.05
Norway	-47.97%	-42.48	3.88%	0.09	-4.51%	-0.07	19.96%	0.02	-3.31%	-52.02	-32.38%	-3.75
Poland	0.77%	0.76	-3.77%	-0.10	12.91%	0.15	9.00%	0.00	-3.57%	-114.66	285.03%	2.70
Portugal	10.79%	7.26	6.13%	0.14	-5.89%	-0.07	-32.55%	-0.92	9.29%	361.02	-17.46%	1.59
Slovakia	1.88%	1.84	-11.44%	-0.26	1.43%	0.02	-59.66%	-0.02	-1.89%	-62.85	-66.34%	-8.40
Slovenia	1.94%	1.90	8.08%	0.18	3.99%	0.05	-42.75%	-0.01	-1.03%	-37.06	25.43%	0.19
Spain	-1.39%	-0.95	1.55%	0.04	-17.50%	-0.23	-4.31%	-0.05	0.15%	5.56	3.56%	2.11
Sweden	2.51%	2.40	-1.64%	-0.03	4.77%	0.06	-31.18%	-0.01	-1.32%	-33.29	-8.36%	-0.29
Switzerland	1.16%	1.14	2.86%	0.07	1.89%	0.03	122.91%	0.18	-1.78%	-54.15	18.21%	2.06
Türkiye	6.68%	5.54	8.47%	0.20	-6.25%	-0.11	46.18%	0.59	8.35%	250.11	0.89%	2.73
United Kingdom	0.01%	0.01	3.56%	0.06	-6.29%	-0.10	-14.07%	0.00	-4.86%	-111.42	-17.55%	-0.86
United States	-0.74%	-0.72	-6.01%	-0.12	-3.41%	-0.05	-17.94%	-0.19	2.56%	120.97	0.08%	1.30

Note: No results are available for Iceland on crop suitability since no cropland cover is detected using SPAM data. No data are available for irrigated area for Iceland and Ireland, and on water withdrawal for irrigation in Belgium. The change in crop suitability is assessed by comparing crop location from SPAM data in 2005 and in 2020. Most of the FAO irrigation data is only available from 2001 onward, so the period from 2001 to 2005 was utilized. Values in the "Difference" columns are computed as the average annual value of the indicator over the period 2015–2020 minus its value for 2000–2005 and is expressed in the same unit than the indicator. Values in the "Growth" columns represent the percentage change between the average indicator value in 2015-2020 and 2000-2005. They are computed as the country's average annual value of the indicator over the period 2015-2020 minus its average value over 2000-2005, divided by its average value over 2000-2005.

How to read: The crop suitability “Difference” column represents the change in the average share of a country’s total agricultural area where the crops grown were moderately to highly suitable to local climate conditions, comparing the periods 2015–2020 and 2000–2005. For example, Switzerland’s value of +1.14 indicates that the proportion of cropland with climate-suitable crops increased by 1.14 percentage points, corresponding to a 1.1% rise in the share of total cropland supporting suitable crop types (Growth column). The crop (livestock) diversity “Difference” column equals the difference between the average Shannon index over the period 2015-2020 and 2000-2005. The water use (water footprint) “Difference” columns report the difference in the average quantity of water withdrawal for irrigation (the quantity of water needed to grow crops) between the period 2015-2020 and 2000-2005. The Irrigation Capacity “Difference” columns represent the difference between the share of total country’s cropland equipped for irrigation in the period 2015-2020 and the same share in the period 2000-2005. The “Growth” columns report the value of these differences divided by the average value over the period 2000-2005. Source: Authors’ own, using data from Crops and livestock products (FAO, 2024[48]), SPAM (IFPRI (2024[51]) and (2019[52])), GAEZ (FAO and IIASA, 2022[49]), Freshwater-Abstractions (OECD, 2024[54]), Waterfootprint (Mialyk et al., 2024[55]) and AQUASTAT (FAO, 2021[53]).

III. Climate Impacts on Agriculture

Table A B.3. Country's score for indicators of dimension III: Climate Impacts on Agriculture

Change in the average deviation of annual crop, meat and milk yields from the previous six-year average, comparing the periods 2000–2005 and 2015–2020

Country	Crop		Meat		Milk	
	Growth	Difference (%p)	Growth	Difference (%p)	Growth	Difference (%p)
Australia	27.5%	0.84	70.9%	1.30	11.7%	0.57
Austria	172.1%	1.94	-58.0%	-0.94	-55.9%	-5.29
Belgium	-404.7%	-5.34	725.0%	1.49	937.5%	12.15
Canada	1913.3%	5.43	78.1%	1.90	48.1%	2.79
Chile	-46.6%	-4.34	-65.9%	-3.41	-115.3%	-31.25
Colombia	-50.4%	-3.67	1212.5%	3.67	2617.0%	42.10
Costa Rica	-3997.1%	-0.58	-64.9%	-1.00	-837.5%	-0.99
Czechia	-38.7%	-2.05	-70.8%	-5.17	-43.7%	-6.68
Denmark	51.6%	0.64	72.7%	1.45	3.1%	0.20
Estonia	-15.0%	-2.32	-141.5%	-10.96	-29.3%	-5.49
Finland	-59.8%	-3.58	-38.0%	-0.95	-33.7%	-3.07
France	-2293.9%	-3.20	154.0%	1.47	-10.2%	-0.39
Germany	-258.5%	-4.72	12.2%	0.10	-29.4%	-2.53
Greece	373.8%	2.30	55.8%	0.70	337.6%	7.52
Hungary	151.9%	7.70	211.0%	2.41	58.8%	3.17
Iceland	-106.6%	-10.04	9.6%	0.21	-13.5%	-1.62
Ireland	-81.0%	-3.47	174.5%	2.12	103.5%	4.70
Israel	-149.9%	-13.38	26.3%	0.70	47.5%	0.22
Italy	-68.7%	-1.20	216.7%	1.89	1126.7%	12.38
Japan	-34.5%	-0.36	24.1%	0.21	15.5%	0.69
Korea	-55.8%	-1.37	100.4%	8.05	-115.7%	-7.77
Latvia	46.3%	4.18	343.7%	3.71	5.8%	0.69
Lithuania	-37.5%	-4.76	106.8%	4.54	-39.9%	-5.33
Luxembourg	-116.2%	-5.23	479.4%	5.90	105.8%	4.90
Mexico	-29.8%	-2.11	91.0%	2.24	376.4%	4.89
Netherlands	-143.9%	-2.63	594.4%	2.24	151.1%	4.59
New Zealand	-7.4%	-0.27	-62.1%	-2.81	2.3%	0.17
Norway	365.5%	6.33	84.1%	0.25	20.2%	0.54
Poland	-80.4%	-2.58	754.2%	3.21	70.2%	5.35
Portugal	4534%	16.65	-77%	-1.62	-181%	-21.15
Slovakia	510.7%	8.00	158.8%	9.10	-25.2%	-1.74
Slovenia	65.3%	1.99	326.0%	1.92	-76.1%	-17.50
Spain	84.0%	4.25	226.3%	2.16	-83.4%	-17.86
Sweden	30.0%	0.79	-6.9%	-0.14	-57.6%	-4.17
Switzerland	-3.9%	-0.04	17.3%	0.29	-87.9%	-6.46
Türkiye	-32.2%	-1.84	106.4%	1.87	-112.4%	-23.44
United Kingdom	-57.6%	-0.70	-41.9%	-1.03	-63.6%	-5.49
United States	55.8%	2.31	-63.2%	-2.46	-30.3%	-1.79

Note: Values in the "Difference" columns are computed as the average annual country level yield fluctuation over the period 2015–2020 minus the average annual country level yield fluctuation for 2000–2005. The "Growth" columns represent the ratio (expressed as a percentage) between the average annual country level yield fluctuation over the period 2015–2020 and that in 2000–2005. It equals the value in the respective "Difference" column, divided by the absolute value of the average annual country level yield fluctuation over the period 2000-2005. OECD level annual yields are computed as the ration between the total annual production (in tons) over all OECD countries divided by the OECD total cropland area (in ha) or the total number of producing animals. The weighted average fluctuation in OECD crop yields is calculated by summing, across all crops grown in the OECD, the annual yield variation for each crop (measured as the difference between its annual yield and the average yield of the previous six years, expressed as a percentage of that six-year average) multiplied by the crop's share of the total harvested area in all OECD countries. The types of crops are identified among the 151 "primary crop" types identified in the Crops and livestock products database of the FAO grown in OECD countries. Livestock species include asses, cattle, chickens, pig, pigeons and other birds, mules, goat geese, ducks, rabbits and hares, buffalo, camels, sheep and turkeys for meat and buffalo, cattle, sheep and goat for milk.
Source: Authors' own, using (FAO, 2024[48]).

IV. Enabling Agricultural Adaptation

Table A B.4. Country’s score and information for dimension IV: Enabling Agricultural Adaptation

Change in the average countries’ share of agricultural adaptation patented technologies in all agricultural patented technologies between the periods 2000–2005 and 2015–2020, total number of adaptation programmes and policies created over the period 1994-2022* and index score of adaptation planning for agriculture.

Country	Innovation in agricultural adaptation technologies		Adaptation programmes and policies	Adaptation planning for agriculture	
	Growth (%)	Difference (%p)	Total number (1994-2022*)	Index score	Reference document(s)
Australia	66.9%	1.54	19	4	National Climate Resilience and Adaptation Strategy 2021 – 2025
Austria	197.8%	2.88	7	6.5	The Austrian strategy for adaptation to climate change: Part I and II (2024)
Belgium	-6.0%	-0.24	3	4.5	Belgian National Adaptation Plan (2017-2020)
Canada	38.6%	1.38	8	5.5	Canada’s National Adaptation Strategy (2023) & Government of Canada Adaptation Action Plan (2022)
Chile	-	4.04	6	7.5	Chile's Long Term Climate Strategy (2021)
Colombia	-76.9%	-3.07	10	6	National Climate Change Adaptation Plan (2016)
Costa Rica	-	0.00	8	9	National Climate Change Adaptation Plan (2022 - 2026)
Czechia	-37.4%	-1.56	9	7	National Climate Change Adaptation Action Plan & Climate change adaptation strategies in the Czech Republic (1st update for the period 2021 - 2030)
Denmark	15.7%	0.50	9	1.5	How to manage cloudburst and rainwater: Action plan for a climate-proof Denmark
Estonia	NA	2.78	3	3.5	Climate Change Adaptation Development Plan until 2030
Finland	24.3%	1.07	4	8	Government Report on Finland’s National Climate Change Adaptation Plan until 2030
France	30.4%	0.76	25	4.5	Presentation document PNACC 3 (DAS 2024, DRAFT)
Germany	15.5%	0.28	12	8	German Adaptation Strategy to Climate Change 2024 (DAS 2024)
Greece	45.2%	2.33	25	4.5	National Adaptation Strategy to Climate Change (2016)
Hungary	-63.7%	-2.65	7	5.5	Second National Climate Change Strategy (2018)
Iceland	-	0.00	1	2.5	In the light of climate change - Policy on adaptation to climate change (2021)
Ireland	-3.4%	-0.04	7	9	Agriculture, Forest and Seafood Climate Change Sectoral Adaptation Plan (2019)
Israel	12.4%	0.89	10	4.5	National Action Plan on Climate Change 2022-2026 (2021)
Italy	22.6%	0.44	7	8	National Plan of Adaptation to Climate Change (2023) (Excel file "Annex iv sectoral adaptation actions")
Japan	106.2%	1.97	14	7	Climate change adaptation plan (2021) and Climate Change Adaptation Plan of Ministry of Agriculture, Forestry and Fisheries (2021) (and additional MAAF document “Adaptation to Climate Change in the Agriculture, Forestry and Fisheries Sectors” (2025))
Korea	150.9%	6.44	11	8.5	3rd National Climate Change Adaptation Measures (2021-2025): Detailed Implementation Plan (2021)
Latvia	66.9%	1.54	5	9	Latvian National Plan for Adaptation to Climate Change Until 2030 (2019)
Lithuania	-	0.00	3	8	National Energy and Climate Action Plan of The Republic Of Lithuania For 2021-2030 (2021)
Luxembourg	197.8%	2.88	1	8	Strategy and Action Plan for Adaptation to the Effects of Climate Change 2018-2023 (2018)
Mexico	-6.0%	-0.24	13	4.5	National Development Plan Special Program Climate Change 2014-2018: 2016 achievements (2016)
Netherlands	38.6%	1.38	13	6.5	National Climate Adaptation Implementation Programme (2023) + Status and follow-up of the Climate Adaptation Action Programme agriculture (2022)
New Zealand	-	4.04	4	8	Aotearoa New Zealand’s First National Adaptation Plan (2022)
Norway	86.3%	1.58	5	4	A changing climate – united for a climate-resilient society (2023)
Poland	-76.9%	-3.07	10	7.5	Polish National Strategy for Adaptation to Climate Change (NAS 2020) with the perspective by 2030 (2013)
Portugal	-	0.00	16	10	Adaptation to Climate Change Action Programme (P-3AC) (2019) Approved by the Resolution of the Council of Ministers Nº. 130/2019 of 2nd of August (2019)
Slovakia	15.7%	0.50	2	9.5	Action plan for implementation of the Climate change adaptation strategies of the Slovak Republic (2021)
Slovenia	15.5%	0.28	6	5.5	Strategic Framework for Climate Change Adaptation (2016) & Strategy For Adaptation Of Slovenian Agriculture And Forestry To Climate Change (2010)
Spain	28.1%	0.99	4	8	National Climate Change Adaptation Plan 2021-2030 (2020)
Sweden	-37.4%	-1.56	7	6	Climate adaptation action plan Swedish Board of Agriculture's (2022)

Switzerland	86.3%	1.58	28	8	Adaptation to climate change in Switzerland Action Plan 2020–2025 (2020)
Türkiye	-	2.78	3	9	Climate Change Adaptation Strategy and Action Plan (2024 - 2030) (2024)
United Kingdom	117.6%	2.18	27	5.5	The Third National Adaptation Programme (NAP3) and the Fourth Strategy for Climate Adaptation Reporting (2023)
United States	28.1%	0.99	41	8	USDA Climate Adaptation Plan 2024-2027 (2024)

Note: The "Difference" column shows the change in the country's share of the number of agricultural adaptation patented technologies over the number of all patented technologies related to agriculture, calculated as the average value for 2015–2020 minus the average value for 2000–2005. The "Growth" column represents the ratio (expressed as a percentage) between the country's share of the number of agricultural adaptation patented technologies over the number of all patented technologies related to agriculture in 2015–2020 and that in 2000–2005.
* The period 1994–2022 represents the earliest and latest publication or submission years of the documents reviewed in the OECD Agricultural Policy Monitoring and Evaluation 2023, from which countries' adaptation programs and policies are extracted.
Source: Authors own, using data from OECD Science Technology and Innovation (STI) Micro-data Lab's Intellectual Property Database (OECD, 2024[63]), Agricultural Policy Monitoring and Evaluation 2023 (OECD, 2023[8]) and review of national planning adaptation documents.

Annex C. Additional figures

Table A C.1. Examples of data constrained indicators

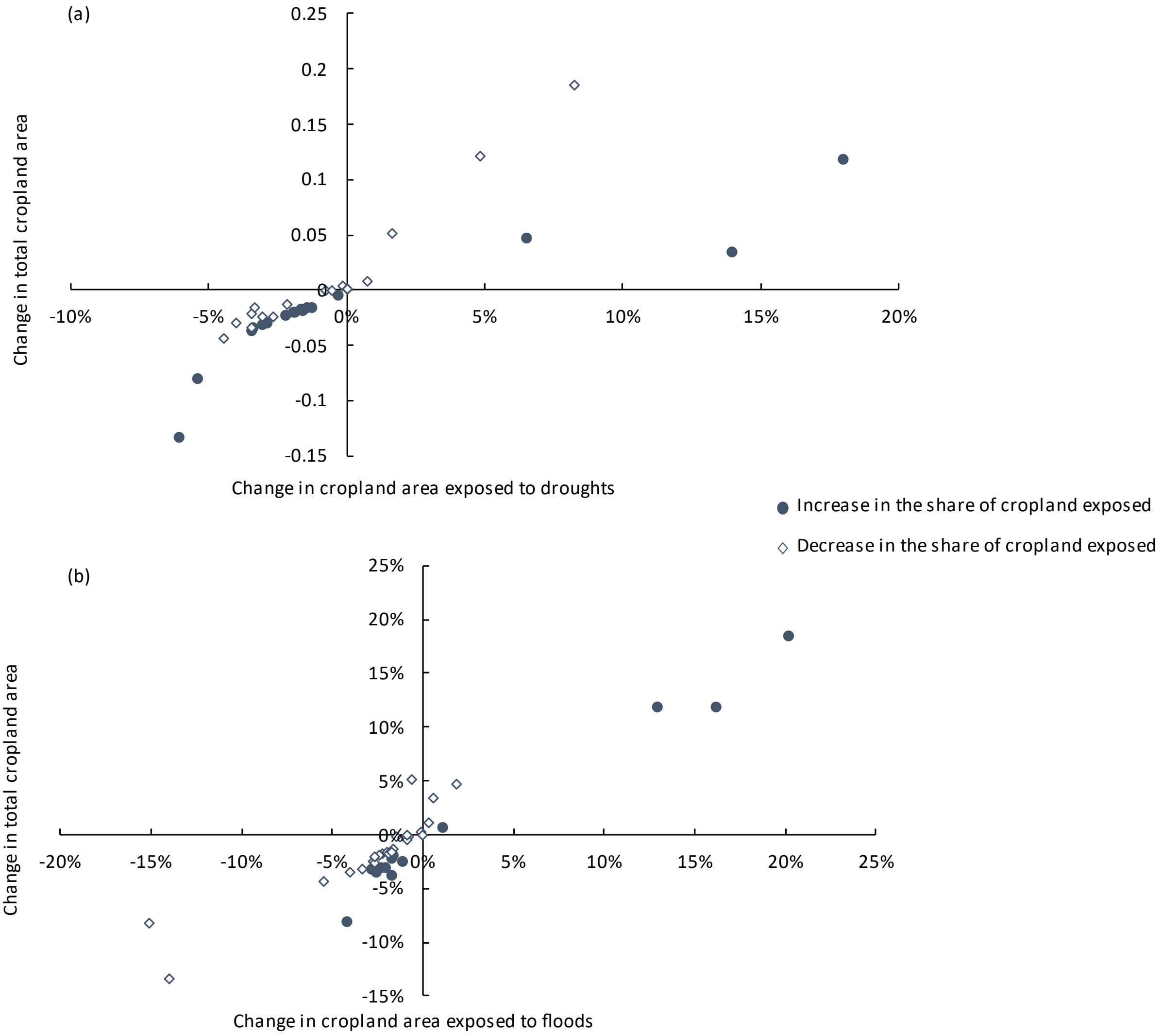
Examples of relevant indicators excluded from this analysis due to data limitations

Dimension	Indicator	Available data sources	Data limitations
Dimension II: Resilient Agricultural Practices Reducing Vulnerability	Share of cropland under agroforestry	Corine Land Cover Zomer et al (2016)	Coverage of Europe only (Corine Land Cover) Limited time coverage (up to 2010) (Zomer)
	Total drained cropland area	FAO AQUASTAT	No data for OECD countries
Dimension III: Climate impacts on agriculture	Soil degradation indicator	Soil Threats Data (European Soil Data Centre (ESDAC)) Land degradation in global arable lands (Prăvălie et al., 2021)	Coverage of Europe only (ESDAC) Limited time coverage (single year 2012)
	Soil erosion	Global Soil Erosion Modelling platform (Borrelli et al. 2017)	Limited time coverage (20001 and 2012 only)
Dimension IV: Enabling conditions	Public spending for agricultural adaptation	Agricultural financial support (OECD data explorer)	No information on adaptation releated spending
	Farmers training and awareness	NA	NA

Source: Copernicus Land Monitoring Service (2018[91]), Zomer et al. (2016[92]), (FAO, 2021[53]), European Soil Data Centre (ESDAC), Joint Research Centre (2025[93]), Prăvălie et al. (2021[94]), Borrelli et al. (Borrelli et al., 2017[95]) and (OECD, 2024[96]).

Figure A C.1. Cropland exposure and agricultural development in OECD countries

Changes in the share of country’s cropland area and country’s total cropland area exposed to droughts (right) and floods (left) and in total countries’ cropland area between the periods 2000–2005 and 2015–2020.

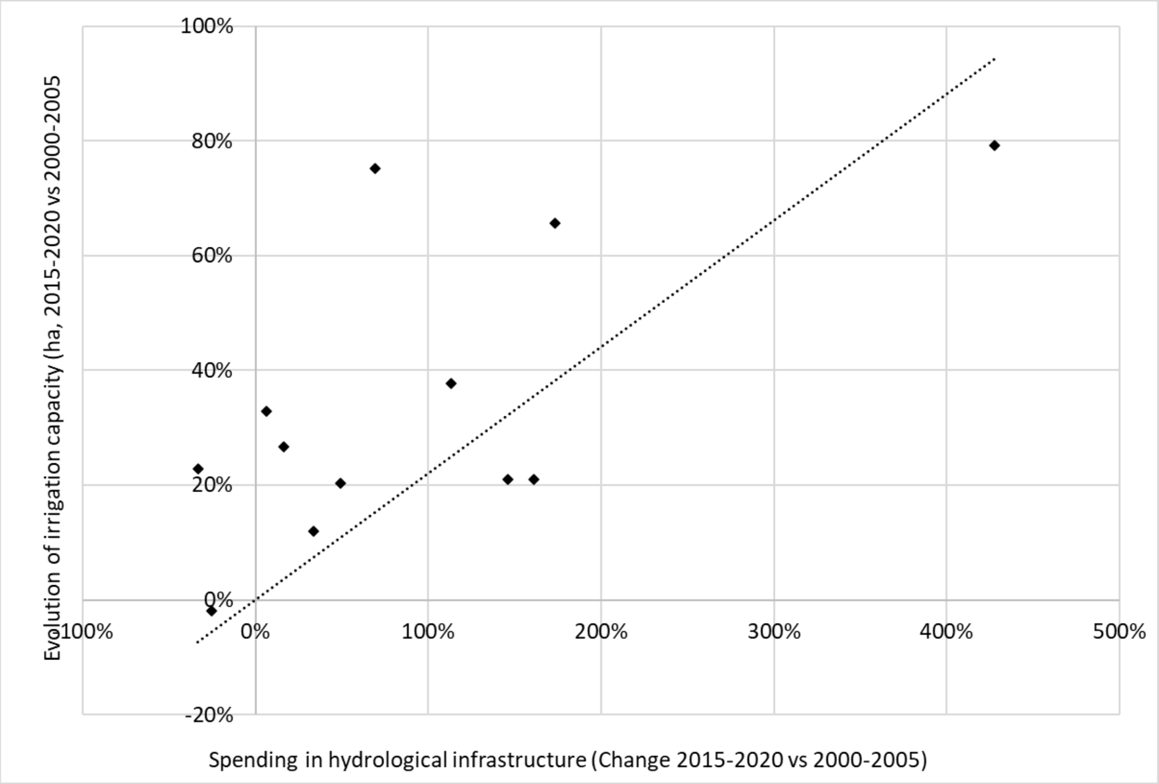


Note: Each symbol represents a country. White symbols represent countries experiencing a decrease in the share of cropland exposed to droughts (a) or floods (b) between the periods 2000-2005 and 2015-2020, and dark symbols countries with an increase in the exposure to these hazards over the same periods. The x-axis shows the percentage change in the total area of country’s cropland exposed to droughts (a) or floods (b) between the period 2000–2005 and 2015–2020. It is computed as the area of cropland located in drought (flood) prone areas in 2015-2020 minus the area of cropland located in drought (flood) prone areas in 2000-2005, divided by the area of cropland located in drought (flood) prone areas in 2000-2005. Similarly, the y-axis shows the percentage change in the total area of country’s cropland between the period 2000–2005 and 2015–2020. It is computed as the total area of cropland in the country in 2015-2020 minus the total area of cropland in the country in 2000-2005, divided by the total area of cropland in the country in 2000-2005.

Source: Authors’ own, using data from Copernicus Global Land Cover (Copernicus Climate Change Service, 2019[38]), Copernicus Climate Change Service (C3S) (Copernicus Climate Change Service, 2018[39]) and Global river flood hazard maps (Baugh et al., 2024[40]).

Figure A C.2. Country's spending in hydrological infrastructure and irrigation development

Change in average country's annual spending in hydrological infrastructure and area equipped for irrigation between the periods 2000-2005 & 2015-2020

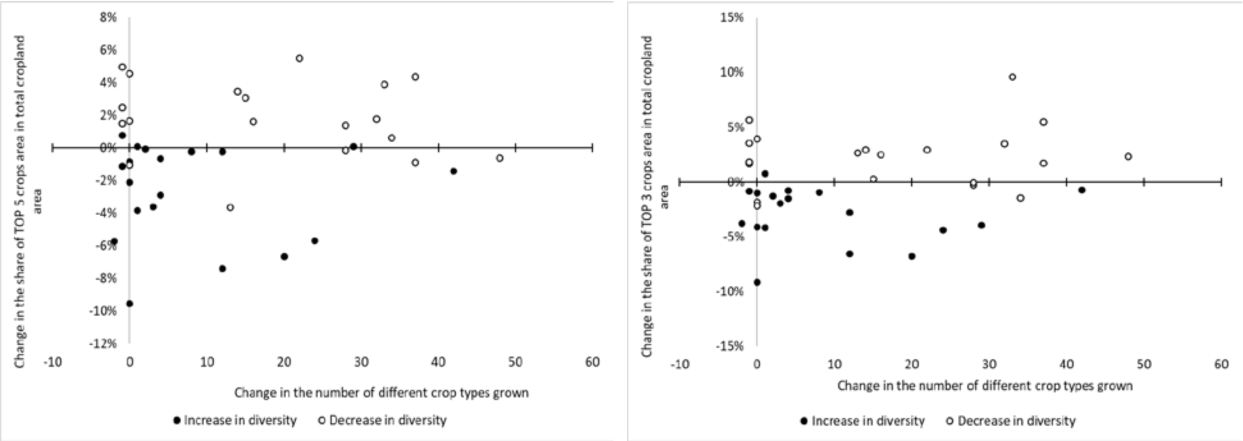


Note: The x-axis represents the percentage change in total amount of funding dedicated to hydrological infrastructure between the periods 2000-2005 and 2015-2020 in constant 2015 USD. It is computed as the total funding over the period 2015-2020 minus 2000-2005, divided by the total funding over the period 2000-2005. Similarly, the y-axis represents the percentage change in total area equipped for irrigation in ha between the periods 2000-2005 and 2015-2020 in constant 2015 USD, and is computed as the total area equipped for irrigation over the period 2015-2020 minus 2000-2005, divided by the total area equipped for irrigation over the period 2000-2005. Each point represents a country or region. Countries (regions) included are Australia, Canada, Chile, Colombia, Costa Rica, European Union, Israel, Japan, Korea, Mexico, New Zealand and Türkiye.

Source: Authors' own, using data from AQUASTAT (FAO, 2021[53]), Agricultural financial support (OECD, 2024[96]) and World Development Indicators (World Bank, 2024[97]) data.

Figure A C.3. Change in the Shannon Index, the number of crops grown and the share of main crops in total production

Changes in the Shannon Crop Diversity Index, the proportion of harvested area occupied by the five (left) and three (right) main crops relative to the total cultivated land area, and the number of distinct crop types grown between the periods 2000–2005 and 2015–2020.

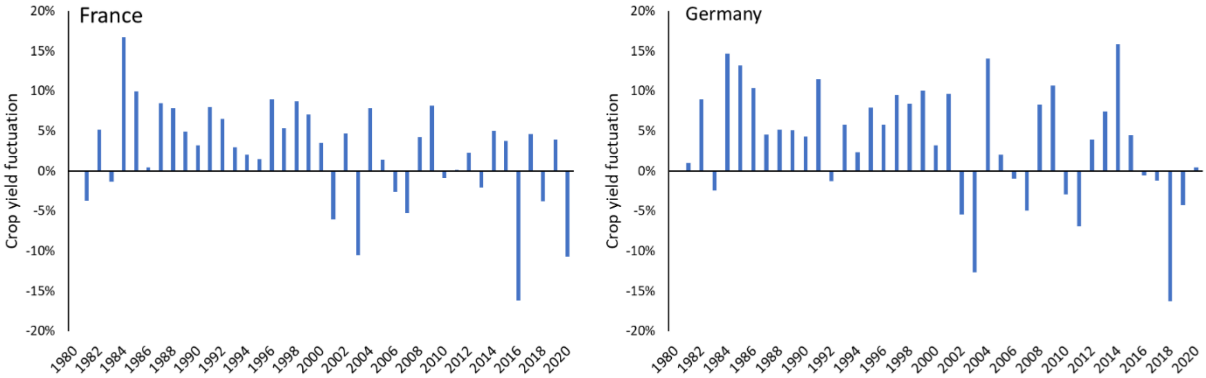


Note: Each point represents a country. White symbols represent countries experiencing a decrease in the Shannon crop diversity index between the periods 2000-2005 and 2015-2020, and dark symbols countries with an increase in this index between the same periods. The x-axis shows the difference in the total number of different crops type grown between the period 2000–2005 and 2015–2020. It is computed as the number of crop types grown in 2015-2020 minus the number grown in 2000-2005. Similarly, the y-axis shows the difference in the average share of harvested area for the five (or three) most cultivated crops in a country as a proportion of the total harvested area and equals the average for the period 2015–2020 minus the average for 2000–2005. The top five (or three) crops in each country are identified based on the total harvested area during the period 2015–2020. The types of crops are identified among the 159 "primary crop" types included in the Crops and livestock products database of the FAO.

Source: Authors' own, using data from Crops and livestock products (FAO, 2024[48]).

Figure A C.4. Average yield fluctuations in France and Germany

Deviation of average weighted annual crops yields with previous 6 years yields average for France (left) and Germany (right), 1981-2020)



Note: Country level annual yields are computed as the ration between the total annual crop production (in tons) in the country divided by the country's total cropland area (in ha). The weighted average fluctuation in country's crop yields is calculated by summing, across all crops grown in the country, the annual yield variation for each crop (measured as the difference between its annual yield and the average yield of the previous six years, expressed as a percentage of that six-year average) multiplied by the crop's share of the total harvested area in the country. The types of crops are identified among the 151 "primary crop" types included in the Crops and livestock products database of the FAO that are grown in OECD countries.

Source: Authors' own, using (FAO, 2024[48]).

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Notes

[1] Climate adaptation is defined as the "adjustment in natural or human systems in response to actual or expected climate in order to moderate harm or take advantage of beneficial opportunities" (IPCC, 2022[1]).

[2] The report also includes "assessing the efficiency and effectiveness of adaptation measures and policies" that is not covered in this analysis.

[3] The Livestock unit (LSU) serves as a reference unit to aggregate livestock across different species (Eurostat, 2024[74]). Data on livestock include asses, cattle, chickens, pig, pigeons and other birds, mules, goat, geese, ducks, rabbits and hares, buffalo, camels, sheep and turkeys for meat and buffalo, cattle, sheep and goat for milk. The average livestock unit coefficient value for cattle is 0.71, similar to European Union (2023[98]).

[4] The SPAM data are available at the global level for the years 2000, 2005, 2010, 2020.

[5] SPAM data covers 27 food crops (wheat, rice, maize, barley, pearl millet, small millet, sorghum, other cereals, potato, sweet potato, yams, cassava, other roots, bean, chickpea, cowpea, pigeon pea, lentil, other pulses, soybean, groundnut, coconut, banana, plantain, tropical fruit, temperate fruit, vegetables) and 15 non-food crops (oil palm, sunflower, rapeseed, sesame seed, other oil crops, sugarcane, sugar beet, cotton, other fibre crops, arabica coffee, robusta coffee, cocoa, tea, tobacco, rest of crops) categories.

[6] OECD irrigation data are used if they cover at least 3 years for both the periods 2000-2005 and 2015-2020. Otherwise, FAO AQUASTAT data on irrigation are used following the same criteria. If the coverage of irrigation data is insufficient (more than 3 years missing for any of the two period for both AQUASTAT and OECD), the ratio of water use for irrigation over total water withdrawal for agriculture is computed for available years using FAO AQUASTAT data, and water use for irrigation is computed as this ratio times total water withdrawal for agriculture from AQUASTAT.

[7] The 21 OECD countries included are: Austria, Canada, Colombia, Denmark, Estonia, Finland, France, Hungary, Italy, Japan, Latvia, Lithuania, New Zealand, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, USA.

[8] The CPC codes Y02A40/80, Y02A40/81, Y02A40/818, Y02A40/90, Y02A40/924, Y02A40/926, Y02A40/928, Y02A40/963, Y02A40/966 are excluded as they refer to fisheries, aquaculture or food production related technologies.

[9] The CPC codes Y02A40/81, Y02A40/818, Y02A40/90, Y02A40/924, Y02A40/926, Y02A40/928, Y02A40/963, Y02A40/966 are excluded as they refer to fisheries, aquaculture or food production related technologies.

[10] UNFCCC communications include National Communications (NC), Nationally Determined Contributions (NDCs) and Adaptation Communications.

[11] Ducks are excluded from the analysis are this category was not available for the 2020 version of the GLW data.

[12] The list of countries covered is available in the OECD Agricultural Policy and Monitoring report (OECD, 2023[8]).

This paper presents a list of indicators for monitoring progress in adapting agricultural production to extreme weather events. It details the methodology used to select and build these indicators and presents their application in all OECD countries. Adaptation progress is assessed across four key dimensions: (1) the exposure of agricultural production to extreme weather events, (2) the adoption of resilient agricultural practices to reduce vulnerability, (3) the impacts of extreme weather events on agricultural production, and (4) the conditions enabling agricultural adaptation. These indicators aim to inform country- as well as cross-country-level assessment of progress in agricultural resilience building over time.

For more information:

https://www.oecd.org/en/topics/climate-adaptation-and-resilience.html

OECD