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EUROSISTEMA

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# EURO-AREA PHYSICAL RISK INDICATORS FOR CLIMATE-RELATED FINANCIAL STABILITY ANALYSES

by Francesco Cusano*, Danilo Liberati*, Valentina Michelangeli* and Francesca Rinaldi*

**Abstract**

Climate-related physical risks can affect financial stability at a global level. Developing harmonized and comparable indicators is crucial for accurately assessing the potential risks that climate change-driven natural disasters pose to financial markets. These metrics evaluate the exposure of financial institutions' loans and securities portfolios covering a wide range of hazards, assuming different scenarios and incorporating various factors such as collateral, loans' maturity and flood defences. Exploiting the ECB physical risk indicators, this paper describes the key results for Italy as compared with the main euro-area countries. The results indicate that the risks to financial portfolios are expected to increase, especially under the pessimistic climate scenario, in Italy as well as in the rest of the euro area. The findings underscore the importance of adopting climate adaptation measures and incorporating climate risks into portfolio management, in order to reduce future losses and ensure the resilience of the financial system.

**JEL Classification**: G21, P48, Q54.

**Keywords**: physical risks, natural hazards, climate scenarios, financial stability.

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# 1. Introduction[1]

Nowadays, climate change has become one of the main issues faced by policy-makers and regulators (Campiglio et al., 2023). In particular, recent extreme weather events – such as the flooding occurred in Italy and Spain – have renewed interest in the implications of physical-related risks in financial markets. As stated by Faiella and Natoli (2018) the credit channel may be one of the main mechanisms by which natural catastrophes affect the economic system, reducing the ability of borrowers to repay loans and, then, eventually forcing banks to fire sale assets and ration credit.

The measurement of such risks has become a pivotal task under the financial stability . Chabot and Bertrand (2023) assess the role of climate risks for the financial stability of the European financial system showing that, among the physical risks, temperature anomalies, heat waves, wildfires and droughts are the most significant hazards to take into account for regulators. Along these lines, ECB (2020) and EBA (2021) defined climate-related and environmental risks in order to provide a greater transparency for the market about the ECB banking supervisors' expectations on this topic. According to EBA (2021),[2] a physical risk relates to "*any negative financial impact on the institution stemming from the current or prospective impacts of the physical effects of environmental factors on its counterparties or invested assets*". *De facto*, a physical risk can also be regarded as the combination of the information on hazards (intensity and frequency of the natural event), the exposed area/asset and its vulnerability (predisposition, tendency, or deficiency; see also Antofie et al., 2020).

Including both physical and transition risks, Alogoskoufis et al. (2021) developed economy-wide climate stress tests providing a granular exercise about the banks' credit and market portfolios at exposure level, which shows that climate risks are more concentrated in specific sectors or geographical areas highly exposed to physical risk. ECB (2022) focuses on the factors which must be considered when developing climate-related financial risk metrics: refining climate exposure mapping and defining amplification channels should be integrated with scenario analysis considering the different time horizons, possible carbon concentration paths, policies against the climate change, uncertainty and the portfolios' evolutions.

The definition of a set of physical risk indicators depends on the data which are available – in most cases provided by commercial providers – and on the assumptions considered. In 2021, the ECB presented the action plan to include climate change considerations in its monetary policy strategy.[3] From the statistical perspective, the construction of harmonized and comparable indicators was the main objective of the work carried out to release climate change-related statistical indicators owning such characteristics and documented in ECB (2024). Among them, the physical risk ones evaluate the impact of natural events on the exposure of

[1] We thank Paolo Angelini, Emilia Bonaccorsi Di Patti, Alessio De Vincenzo, Laura Mellone and Roberto Sabbatini for useful comments on earlier versions of the paper. The views expressed in the paper are those of the authors and do not involve the responsibility of the Bank of Italy.

[2] For more details see the glossary, page 7 of EBA (2021).

[3] See https://www.ecb.europa.eu/press/pr/date/2021/html/ecb.pr210708_1~f104919225.en.html.

financial institutions' loan and securities portfolios covering a wide range of hazards and exploiting available and – where it is possible – public information for the European System of Central Banks (ESCB) like that of the EU Joint Research Centre (JRC). The gain in comparability due to the usage of harmonized data sources may contrast with the greater precision that may be obtained by employing national data which are not available or cannot be shared with the ESCB due to contractual arrangements. Empirical analysis available for Italy have been carried out by Meucci and Rinaldi (2022), who estimate the percentage of loan portfolios at risk by adopting the provincial and municipal classifications of the National Plan for Adaptation to Climate Change (NPACC), and by the Italian Institute for Environmental Protection and Research (ISPRA).

ECB indicators on physical risk evaluate the impact of extreme natural events related to climate change on the performance of financial institutions' portfolios, assuming their composition does not change over time. Financial institutions' assets are typically exposed to non-financial corporations in terms of loans granted or securities held. In case of a natural disaster the damages in the productive system of a certain location can be transmitted to the financial system as companies may find it difficult to repay their debts. In this framework the impact of physical risks on financial portfolios can be summarized by two different metrics, related to risk scores and to expected losses, respectively. The former allows only an assessment of the exposure to hazards, which captures the maximum potential impact of a shock on banks' portfolios in a given location; the latter exploits the vulnerability information by specific damage functions that translate the intensity of a hazard (wind speed, water depth, etc.) affecting an area/asset to the ratio of the repair cost of a building to its replacement value (cost to rebuild the entire structure) and, then, to damage values expressed in monetary terms. Moreover, further specifications of indicators can be provided based on the nature of the underlying data: baseline metrics computed using historical information can be compared with forward-looking measures focusing on different climate scenarios and time horizons. All in all, these overviews may change by taking into account other factors such as adaption measures or the presence of insurance and/or collateral claims: insurance may mitigate damages caused by natural catastrophes (Fache Rousová et al., 2021), whereas collateral could act both as attenuation and amplification factor based on the nature – financial or physical – of the guarantees (Meucci and Rinaldi, 2022).

The contribution of this paper is twofold. First, we illustrate the ECB climate change-related statistical indicators focusing on the physical risk ones. The indicators assess acute natural disasters (e.g., flooding, wildfires) and chronic risks (drought and water stress). Notably, they are based on publicly available data, ensuring transparency. Two indicators reflect physical risk levels, while two others estimate expected monetary losses. All the ECB indicators use historical data, with projections available for certain hazards, focusing on medium-term scenarios to incorporate potential effects of human actions, particularly greenhouse gas emissions, on future climate and weather events. Second, we present a comparison of the harmonized indicators developed by the ECB for euro area countries, with a particular emphasis on Italy. The analysis compares the indicators based on historical risk data with those that integrate future climate projections, focusing on drought, water stress, wildfires, and floods. While drought risks show a moderate increase, Italy's exposure remains in line with the euro area average. On the contrary, Italy faces considerable challenges in terms of water stress, with risks expected to rise significantly by 2040. Although wildfire risk is generally lower, Italy's exposure remains higher than the euro area average. Flooding risks in the euro area are currently low but may increase, as flood defences are anticipated to become less effective in the future, particularly in coastal areas.

The rest of the paper is structured as follows. The next section describes the environmental and financial databases whereas section 3 reports the implemented methodology as well as the definition of the metrics. Section 4 illustrates results with a particular attention to the hazards that most affect Italy. Section 5 reports the main indicators' issues and possible improvements that could be undertaken in the next releases. Section 6 concludes.

## 2. Data

Physical risk indicators are based on information from different data sources with the aim of developing "harmonized" metrics at the European level. Two key sources of information are needed: *i)* environmental data and *ii)* financial information both for banks and non-financial corporations.

### 2.1 Environmental data

The ECB analytical indicators cover a number of acute natural disasters (such as flooding, windstorms, wildfires or droughts) as well as chronic physical risks (heat and water stress). The physical hazard data used to construct the indicators are entirely based on public sources, which assures a transparent methodology, the possibility to share data and regular updates. Nearly the entire EU is covered, and at least 95 percent of the entities registered in the EU are represented for each hazard type.

For all physical risks, the indicators rely on historical data on the hazard events (and their intensity) occurred in the past. However, except for windstorm, landslide, and subsidence, hazard projections are also provided by the Intergovernamental Panel for Climate Change (IPCC), primarily focusing on the medium term. These projections are based on two Representative Concentration Pathways (RCP) scenarios: RCP 4.5 (moderate mitigation) and RCP 8.5 (high emissions or "business as usual"). The inclusion of the projected data allows also for the integration in the indicators of the possible effects of human behavior, particularly in terms of greenhouse gas (GHG) emissions,[4] which significantly impacts future climate and extreme weather events.

Information on flooding is the most comprehensive,[5] covering the severity of coastal and river floods, monetary damages, adaptation measures like flood defenses, and projections under different climate scenarios. Coastal flood risk is influenced by storm surges, tides, sea level rise and coastline changes. It is important to remark that these forces may act in opposing directions in future projections. Environmental data on EU countries indicate that the highest flood risks

[4] Based on the GHG protocol, the GHG emissions include CO2, CH4, HFC, NF3, SF6, N2O and PFC.
[5] Source: University of Delft.

are in the North and Baltic Sea areas, with the German coastline facing the highest extreme water levels. The Netherlands is also at significant risk, followed by Belgium and Italy. These estimates exclude flood defenses, which are strongest in Northern Europe and, while models show good accuracy, uncertainties remain. River floods are influenced by heavy rainfall, snowmelt, and rising sea levels, with urban areas facing higher risks due to poor drainage. River flood risks are projected to increase in Germany and France, but decrease in Scandinavian countries like Finland. Flood defense assumptions impact risk assessments, and effective adaptation measures include detention areas, dyke systems, flood-proofing buildings, and relocation. Flood defense levels across Europe are based on actual protection standards, quantified in terms of flood return periods.

Wind damage is primarily caused by gusts (brief, high-speed wind blasts) and prolonged strong winds. The windstorm intensity is measured by its gust speed, while damage is estimated by analyzing gust speeds for specific return periods and storm frequency. Monetary losses are available also for windstorm risk. The impact of climate change on windstorm patterns in Europe remains unclear but windstorms are still a major hazard, making their inclusion in physical risk assessments essential.[6]

A landslide refers to the downward movement of rock, soil, or debris along a slope, typically triggered by factors such as heavy rainfall, earthquakes, volcanic eruptions, rapid snowmelt, or human activities like deforestation. The landslide risk indicator uses a matrix approach, which combines terrain features with probabilistic daily maximum precipitation. The risk scores, similar to those for flood risk assessments, account for multiple return periods.[7]

Subsidence refers to the sinking or settling of a portion of the earth's crust, which can be caused by human activities or natural processes such as the expansion and contraction of soils based on moisture levels. Its likelihood increases with rising sea levels, drought, and earthquakes. While the probability of subsidence events is not yet available, risk assessments are mainly based on soil clay content.[8]

A wildfire is an uncontrolled fire that spreads in natural areas, which can be triggered by human activity or natural events. In recent years, wildfires have become an increasing challenge in Europe. Portugal, Greece, and Spain are expected to face a significant rise in risk by 2050, while the Baltic region may experience lower or similar risk due to warmer but more humid conditions. Under the RCP 8.5 scenario, the expected increase in the median fire risk in Italy is approximately 7 percent.[9]

Water stress is defined as the ratio of total water withdrawal to available renewable surface water. This ratio reflects the level of competition for water and helps estimate the severity of freshwater scarcity. A higher ratio indicates greater competition for water resources. These

[6] The final estimates of windstorm risk are based on Copernicus WISC and ESCB calculations.
[7] Source: DRMKC RDH (JRC).
[8] Source: DRMKC RDH (JRC).
[9] Copernicus. The final estimates are the result of ESCB calculations.

ratios are then translated into risk scores, ranging from "low water stress" to "extremely high-water stress".[10]

Droughts are prolonged periods with significantly below-average moisture, affecting large areas and causing water shortages that negatively impact natural systems and economic sectors. They can take various forms, such as meteorological (precipitation deficits), agricultural (crop failure due to soil moisture deficits), ecological (plant stress leading to tree mortality), and hydrological (water shortages in streams or reservoirs). For the climate risk indicators, the focus is on meteorological droughts, using two measures suggested by the IPCC: Consecutive Dry Days (CDD) and the Standardized Precipitation Index (SPI). A consecutive dry day (CDD) is defined as a day with less than 1 mm of precipitation, following at least one previous day with similar conditions. CDD is useful for measuring extreme precipitation events and seasonal droughts. However, the threshold for what constitutes a drought based on consecutive dry days varies by geographical location and typical climate conditions. The SPI compares six-month accumulated precipitation to long-term averages, with negative values indicating drought conditions. While the SPI allows for comparison across regions, it does not account for evaporation. Current projections suggest Northern Europe will see more frequent rainfall, while Southern Europe faces the risk of worsening drought conditions.[11]

### 2.2 Financial information

Data on the portfolios of financial institutions is obtained by ESCB databases. The indicators consider both loans and securities held. From AnaCredit (AC) we retrieve individual loan-level data reported by deposit-taking corporations except central banks (S122) to euro area non-financial corporations (S11) covering a large set of instruments such as overdrafts, credit lines and term loans.[12] AC also provides detailed information on the collaterals as well as the their providers (and their locations): at the end of 2022, in Italy, almost 40 percent of the loans were unsecured and a similar share (39 percent) relates to financial collateral (Figure 1). Moreover, information on loans' maturities is a relevant factor for the calculation of physical risk metrics given the long-term nature of the hazards we study.

Information about the holding of securities (equities and bonds) are obtained by the Securities Holdings Statistics by Sector (SHSS) database which reports various details including instrument type and holders' sector at the security level.

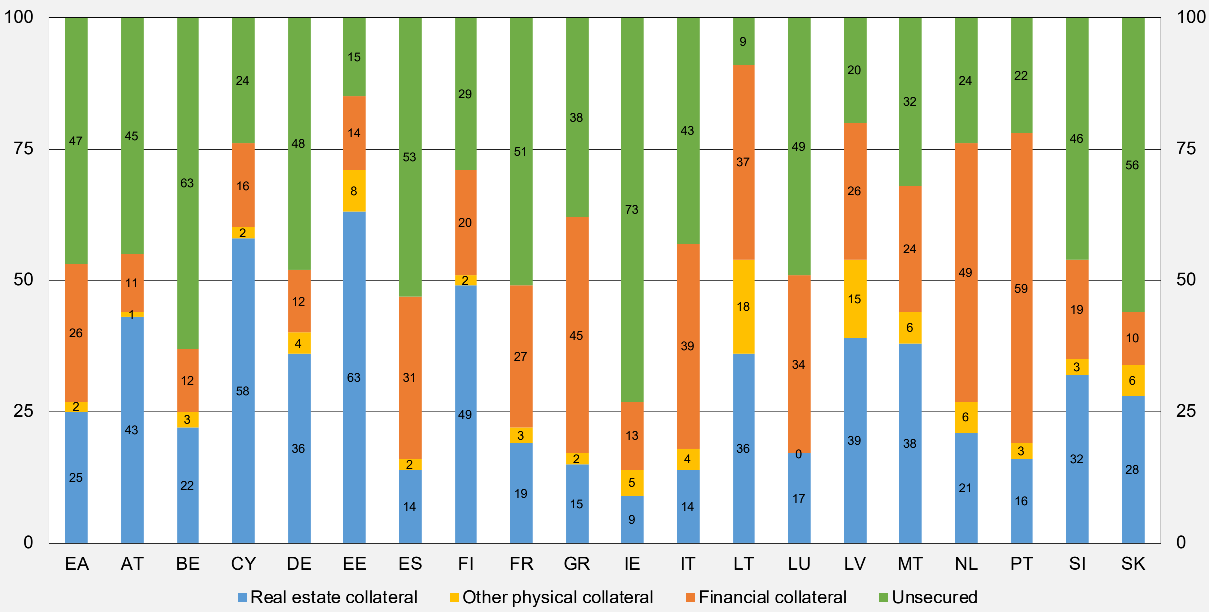
Balance sheet and income statements' variables related to firms (revenues, total assets, number of employees, etc.) are obtained by different data sources. The main reference database is the ECB Register of Institutions and Affiliates Database (RIAD).[13] As for specific variables (e.g. non-financial corporations' tangible fixed assets), we rely on the commercial provider Orbis or, if usable, national registers.

[10] Source: Aqueduct WRI.
[11] Source: IPCC.
[12] AnaCredit presents a reporting threshold equal to 25,000 euros.
[13] RIAD is also used to connect and merge information about the counterparts' location with the levels of hazards, exposure, and vulnerability.

Firms' financial information may have missing values: after testing different imputation specifications (see ECB, 2024), we opt for an indirect method based on ratios for total assets and revenues and for a median approach for the number of employees in order to maintain a good dimension and consistency of the sample.[14] Table 1 shows the coverage by variable distinguishing between reported and estimated values for all counterparties in the AnaCredit database.

**Figure 1**

**Loan volumes by types of collateral and creditor country**
*(percentage values)*




Source: ECB calculations based on AnaCredit data. Reference period: December 2022.

**Table 1**

**Reported and imputed financial variables**
*(number of observations and percentage values)*

| Variable | Observations | Reported | Imputed |
|---|---|---|---|
| Total assets | 4,641,637 | 45% | 55% |
| Revenues | 4,641,637 | 74% | 26% |
| Employees | 4,641,637 | 43% | 57% |

Source: ECB calculations on RIAD and Orbis databases. Reference period: December 2022.

## 3. Methodology

ECB indicators on physical risk cover a number of acute natural disasters and chronic physical risks relying both on historical data and on hazard projections (except for windstorm, landslide, and subsidence). The starting point for the constructions of all the indicators is a certain geographical location, namely the address of the non-financial corporations. For each location and each type of hazard is associated a hazard intensity and a probability of occurrence

[14] For more details about the imputation methods see ECB (2024).

under different climate scenarios. The hazard layer is then linked to the exposure layer measuring both the companies' physical assets at risk (buildings, machineries, etc.) and their obligations in terms of loans received or securities (bonds and equities) issued and held by euro area financial institutions. Finally, a vulnerability layer is introduced that translate the losses of physical assets into monetary losses through damage functions. For hazards such as flooding and windstorms, for which all three layers (hazard, exposure, vulnerability) are available, both "risk-based" and "expected losses-based" indicators are calculated. For the other hazards, for which the vulnerability layer is lacking due to difficulties in evaluating damage functions, only "risk-based" indicators are possible.

The ECB indicators on physical risk can be either "risk-based" or "expected losses-based" depending on the availability of the vulnerability layer. In particular, two indicators, the "risk scores" (RS) and the "potential exposure at risk" (PEAR), are based on risk categories, while the "normalized exposure at risk" (NEAR) and the "collateral-adjusted exposure at risk" (CEAR) are based on expected losses. The NEAR and the CEAR are expressed in monetary terms, allowing both the comparability among hazards and the aggregations across hazards; by contrast RS and PEAR are not additive and must be evaluated separately for each hazard.

The "risk scores" indicator (RS) measures, for each hazard, the percentage of financial institutions' portfolio exposed to debtors located in areas varying from no risk (category 0) to maximum risk (category 3):

$$RS_{j \in [0,3]} = \frac{\sum_{i=1}^{N} \left( EXPOSURE_i | SCORE_{i,j} \right)}{\sum_{i=1}^{N} (EXPOSURE_i)} \tag{1}$$

where $j$ is the risk score category and $EXPOSURE_i$ is the financial exposure for a specific portfolio (loans, debt securities and equities) towards company $i$ (single entity level).

The "potential exposure at risk" indicator (PEAR), measures, for each hazard, the percentage of financial institutions' portfolio associated to debtors located in areas at risk, regardless of the hazard's intensity or frequency. It is, in other words, the sum of RS for categories from 1 (low risk) to 3 (maximum risk):

$$PEAR = \frac{\sum_{i=1}^{N} \left( EXPOSURE_i | RS_{i,j}(j > 0) \right)}{\sum_{i=1}^{N} (EXPOSURE_i)} \tag{2}$$

The "normalized exposure at risk" indicator (NEAR) measures, for each hazard, the monetary losses in financial institutions' portfolio due to the inability of companies to honor their debts in case of extreme natural events:[15]

[15] The assumption underlying the indicator is that each NFC's debt is impaired in proportion to the expected losses related to the ratio between physical and total assets.

$$NEAR = \frac{\sum_{i=1}^{N}(FINANCIAL\ RISK\ RATIO_i \cdot EXPOSURE_i)}{\sum_{i=1}^{N}(EXPOSURE_i)} \quad (3)$$

where $FINANCIAL\ RISK\ RATIO_i$ is a proportion of expected physical losses to total assets of company $i$ and it is calculated as the ratio between tangible fixed assets and total assets times the expected loss over the remaining maturity of an instrument ($m$):

$$FINANCIAL\ RISK\ RATIO_i = \frac{Tangible\ Fixed\ Assets_i}{Total\ Assets_i} \cdot EL_i(m) \quad (4)$$

The "collateral-adjusted exposure at risk" indicator (CEAR) measures, for each hazard, the monetary losses in financial institutions' portfolio, mitigated by collateral protection, due to the inability of companies to honor their debts in case of extreme natural events. It is similar to the NEAR but it considers the positive effect of financial collateral in mitigating the expected losses in the loan portfolio:

$$CEAR = \frac{\sum_{i=1}^{N} max[0, (FINANCIAL\ RISK\ RATIO_i \cdot EXPOSURE_i) - CV_i]}{\sum_{i=1}^{N}(EXPOSURE_i)} \quad (5)$$

where $CV_i$ is the collateral calculated at loan contract level.[16]

## 4. Results

The comparison between risk indicators calculated using historical data, therefore considered as a baseline, and those calculated based on prospective scenarios, provides a more comprehensive evaluation of how the risk may evolve under different conditions and assumptions. In our analysis, whenever possible, baseline indicators based on historical data are compared with those obtained applying climate projections under the RCP 8.5 scenario (i.e. the pessimistic one). For flooding, the analysis includes also the effectiveness of flood adaptation measures. Expected losses indicators for floods and windstorms are calculated only for loans.

### 4.1 Scores' indicators

Score indicators for all hazards show that financial institutions' exposure to physical risks is generally consistent with hazard geography.

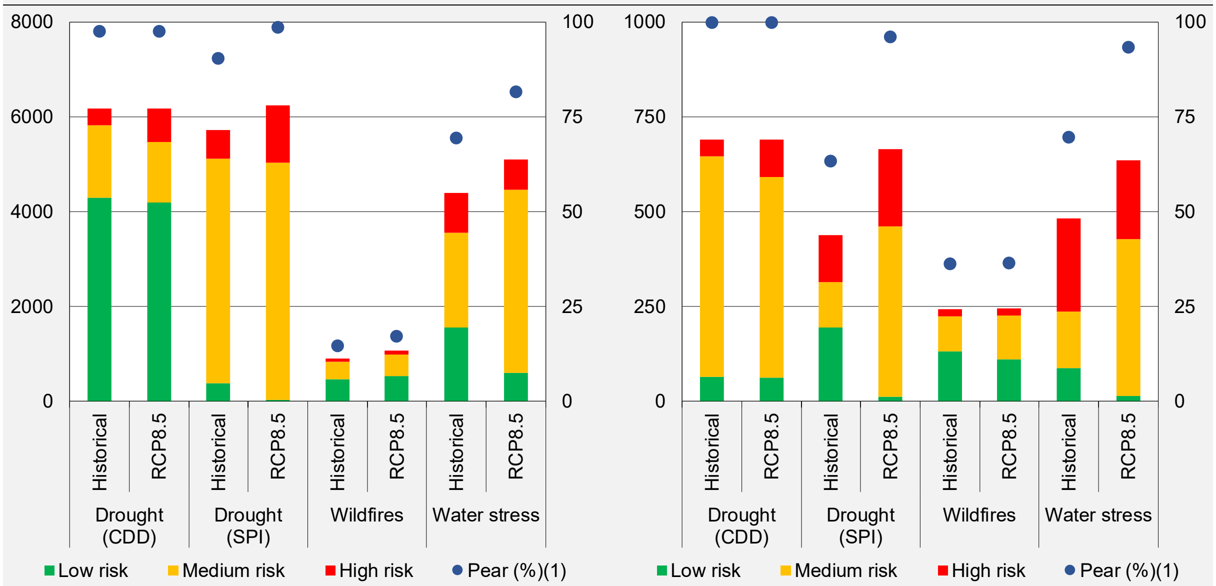
In the euro area (Figure 2a), almost the entire portfolio of financial institutions (approximately euro 6,000 billion) shows a positive risk profile for drought risk, both under the historical baseline and the pessimistic climate scenario. Drought risk is expected to remain relatively stable when assessed in terms of the number of consecutive dry days (Consecutive Dry Days index; CDD), with a slight decrease in the PEAR from 98 to 96 percent over the projected time horizon (2040). However, when considering precipitation levels (Standardized Precipitation Index; SPI), the exposure to risk is projected to increase, as reflected by the PEAR

[16] For more details about the definition of *expected losses over maturity* and *collateral value* see ECB (2024).

rising from 90 to 97 percent. This increase is particularly notable for Italy, where it rises from 63 to 84 percent (Figure 2b).

**Figure 2**

**Exposures to drought, precipitation, water stress and wildfires hazards by risk score**
**Euro area vs Italy**
*(billions of euros; per cent)*




Source: ESCB calculations based on AnaCredit, RIAD, SHSS, IPCC Interactive Atlas, World Resource Institute (WRI), Joint research Centre and Copernicus.
(1) Right-hand scale.

Overall exposure to water stress risk is slightly lower but is expected to consistently increase, rising from approximately 4,000 to euro 5,000 billon, with the PEAR increasing from 69 to 83 percent. Italy already faces a higher exposure to water stress risk, with a PEAR of 70 percent, which is projected to rise to 98 percent by 2040, equating to euro 660 billion in exposure. Wildfire risk in the euro area is relatively low and is expected to remain stable: in particular, it affects around 15 percent of the portfolio, increasing to 17 percent by 2050 under RCP 8.5.

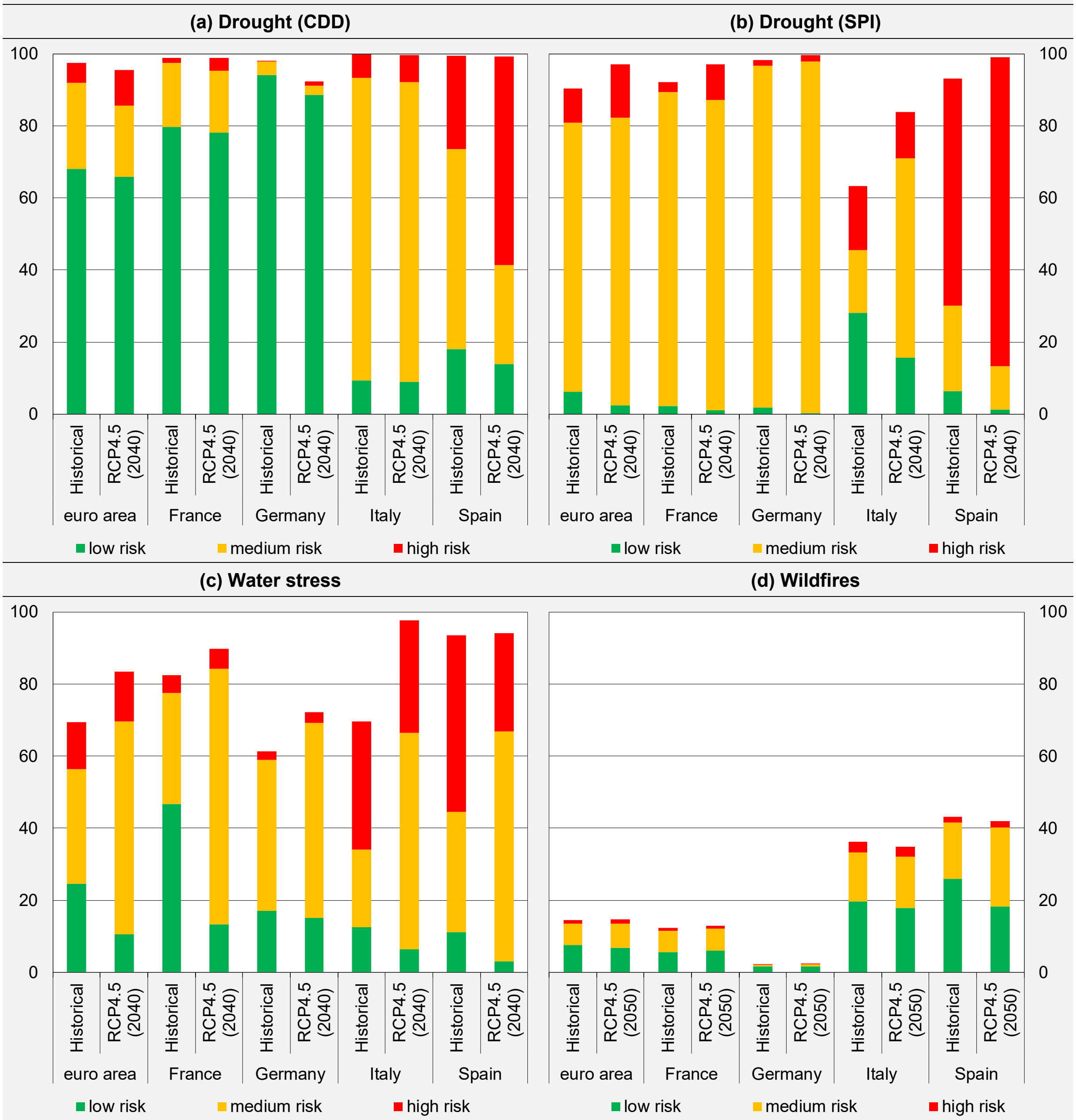
Considering the different levels of risk, the analysis of drought risk provides mixed evidence. CDD fall mainly into the low-risk category (i.e. number of consecutive days without rain of between 15 and 20 days within a year). Projections for 2040 indicate stability in the shares of the portfolio at risk. Although the risk for the Italian system is higher than that of France and Germany, it is almost in line with the euro area average (Figure 3a). Instead, SPI indicator largely shows medium risk. The current exposures of Italian banks to the SPI are predominantly classified in the low-risk category (28 percent of the total) or no-risk category (37 percent). Projections for 2040 show a marked increase in exposures in the medium-risk category, which are expected to exceed 55 percent. Both current and future exposures to SPI risk are significantly lower compared to other major countries (Germany, Spain, France) and the average of the euro area (Figure 3b).

Regarding water stress, current exposures of the Italian financial system are largely classified in the high-risk category (36 percent of the total); by 2040, a significant increase in exposures to medium risk (60 percent of the total) is anticipated, accompanied by a slight decrease in exposures to high risk. Compared to the euro area average, water stress presents a greater source of risk for the financial system both today and in 2040 (Figure 3c).

For what concerns wildfire risk, the current exposures of Italian banks are predominantly classified in the no-risk category (64 percent of the total). Projections for 2040 under the baseline scenario do not show a significant increase in risk exposures; however, both current and future exposures to risk are significantly higher than the average of the euro area, and only slightly lower than Spain (Figure 3d).

**Figure 3**

**Exposures to drought, water stress and wildfires hazards by risk score by country**
*(per cent)*

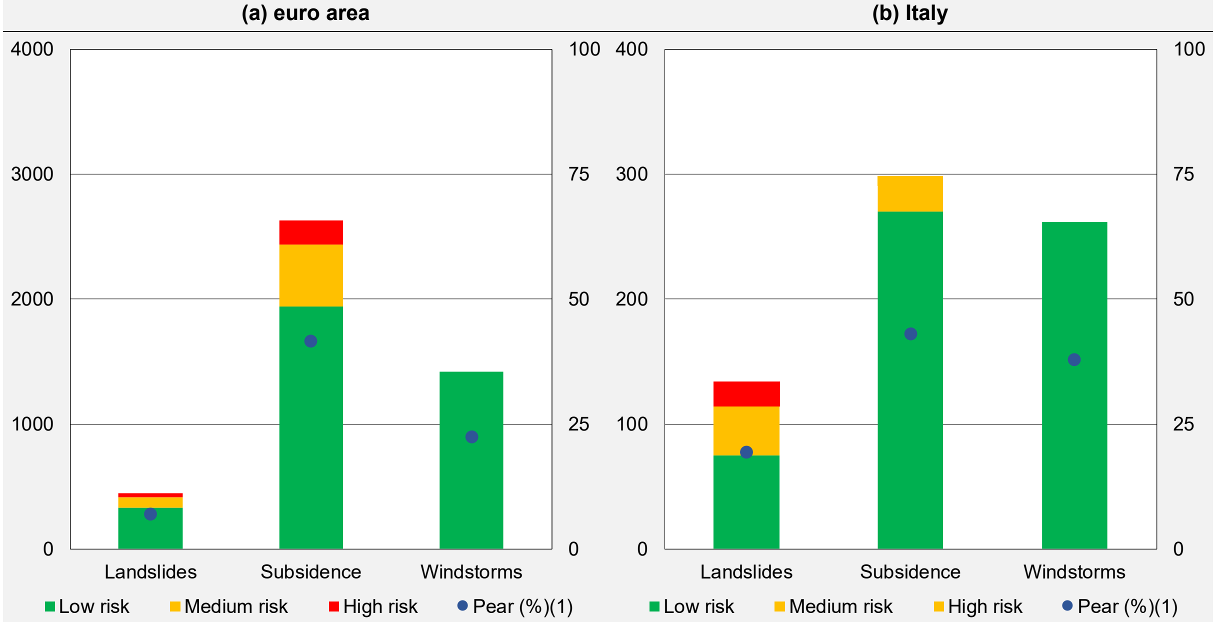



Source: ESCB calculations based on AnaCredit, RIAD, SHSS, IPCC Interactive Atlas, World Resource Institute (WRI), Joint research Centre and Copernicus.

Three hazards – landslides, subsidence, and windstorms – lack forward-looking measures, though they impact significant portions of portfolios even though at low risk. Windstorms show predominantly low-risk scores, partly due to robust European building designs (Figure 4).

**Figure 4**

**Exposures to landslide, subsidence and windstorms hazards by risk score**
*(billions of euros; per cent)*




Source: ESCB calculations based on AnaCredit, RIAD, SHSS, IPCC Interactive Atlas, World Resource Institute (WRI), Joint research Centre and Copernicus.
(1) Right-hand scale.

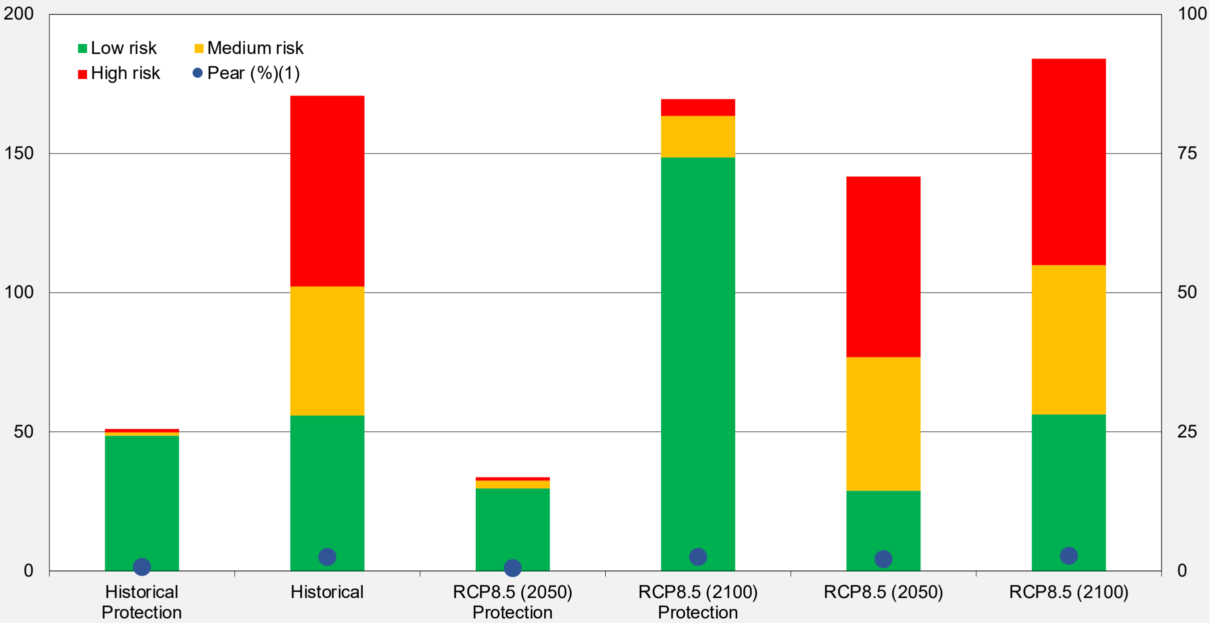
Flood risks are examined in more detail, showing a small proportion of the portfolio affected historically. Under climate scenarios the affected share grows, but flood defences mitigate this risk, particularly for coastal flooding. In the euro area, despite current protections, existing flood defences may not be sufficient to handle more intense future floods, especially for coastal areas under the RCP 8.5 scenario. Without further strengthening of the current defensive systems, flood risks are projected to increase, particularly by the end of the century (Figure 5).

The percentage of the Italian portfolio exposed to river flood risk is generally contained, with only a slight increase expected by 2050, under both scenarios. In comparison to the euro area, the share of exposures in the medium and high-risk categories is similar, while the share in the low-risk category is lower (Figures 6 and 7).

**Figure 5**

## Exposures to coastal flooding hazards by risk score in the euro area

*(billions of euros; per cent)*

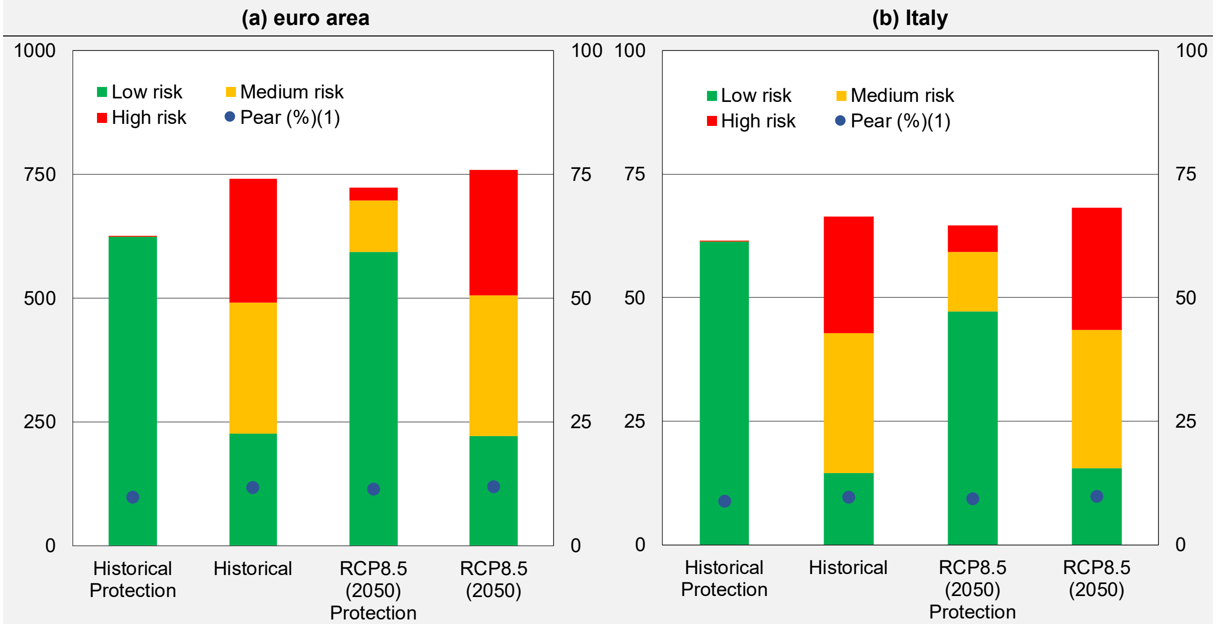



Source: ESCB calculations based on AnaCredit, RIAD, SHSS, and Delft University of Technology (TUD), for flood protection standards on Joint Research Centre (JRC).
(1) Right-hand scale.

**Figure 6**

## Exposures to river flooding hazards by risk score

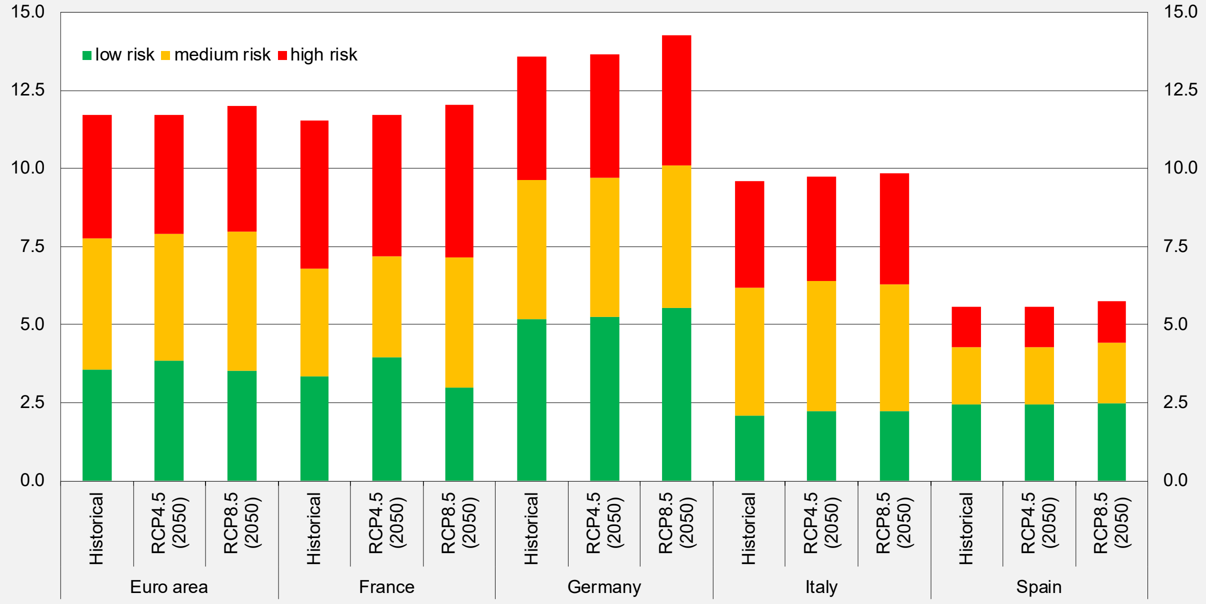
*(billions of euros; per cent)*




Source: ESCB calculations based on AnaCredit, RIAD, SHSS, and Delft University of Technology (TUD), for flood protection standards on Joint Research Centre (JRC).
(1) Right-hand scale.

**Figure 7**

**Exposures to river flooding hazards by risk score**
*(per cent)*




Source: ESCB calculations based on AnaCredit, RIAD, SHSS, and Delft University of Technology (TUD), for flood protection standards on Joint Research Centre (JRC).

### 4.2 Indicators of expected losses

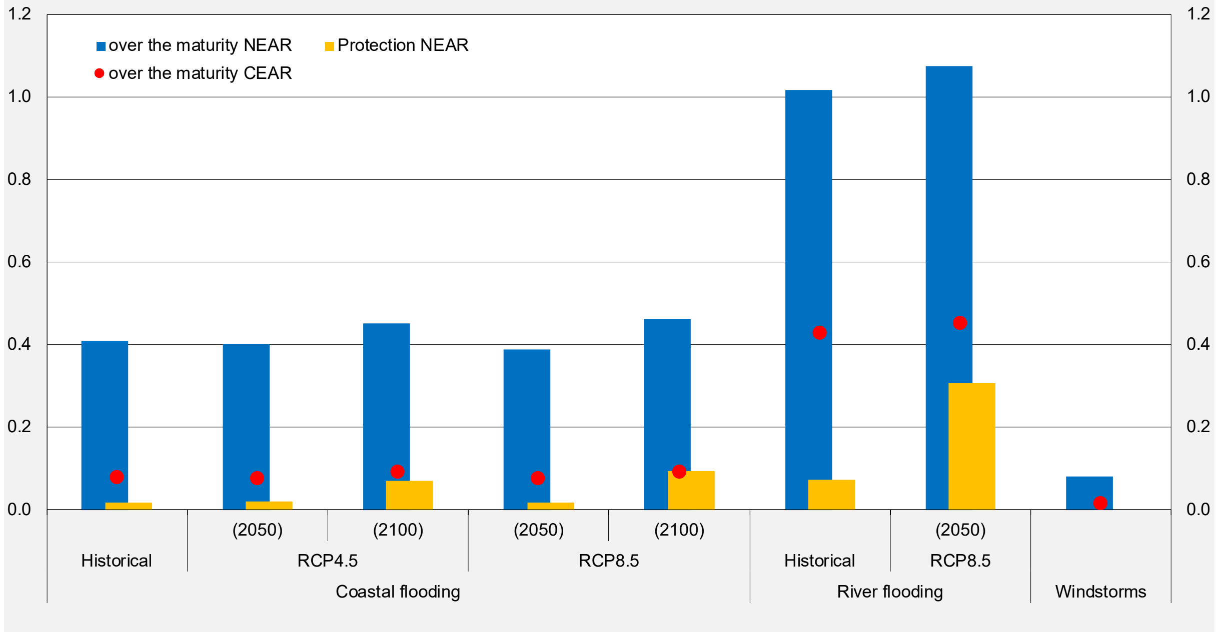
The indicators Normalised Exposure at Risk (NEAR) and Collateral-Adjusted Exposure at Risk (CEAR) are currently quantified for loans, considering the relevance of maturity and collateral. When maturity effects are considered, expected losses from river flooding exceed 1 percent of loan portfolios, coastal flooding impacts 0.4 percent of the portfolio, while windstorms have the smallest impact at 0.1 percent (Figure 8). Flood defences substantially reduce expected losses, with reductions of over 90 percent for both river and coastal flooding. However, these defences are expected to become less effective under future climate scenarios, particularly for coastal flooding by the end of the century unless strengthened. The distribution of NEAR across countries (Figure 9) depends on climate risk, asset exposure, and bank portfolio composition (for example, for coastal flooding, Italy ranks lower than expected due to a lower share of firms' fixed assets compared to other European countries).

The CEAR indicator incorporates collateral, showing its role in mitigating losses in bank portfolios. For river floods, collateral reduces expected losses by 58 percent across the euro area, and for coastal floods and windstorms, the reduction is over 80 percent. The CEAR indicator obviously reflects national collateral practices, such as the share of unsecured loans and the type of collateral pledged.

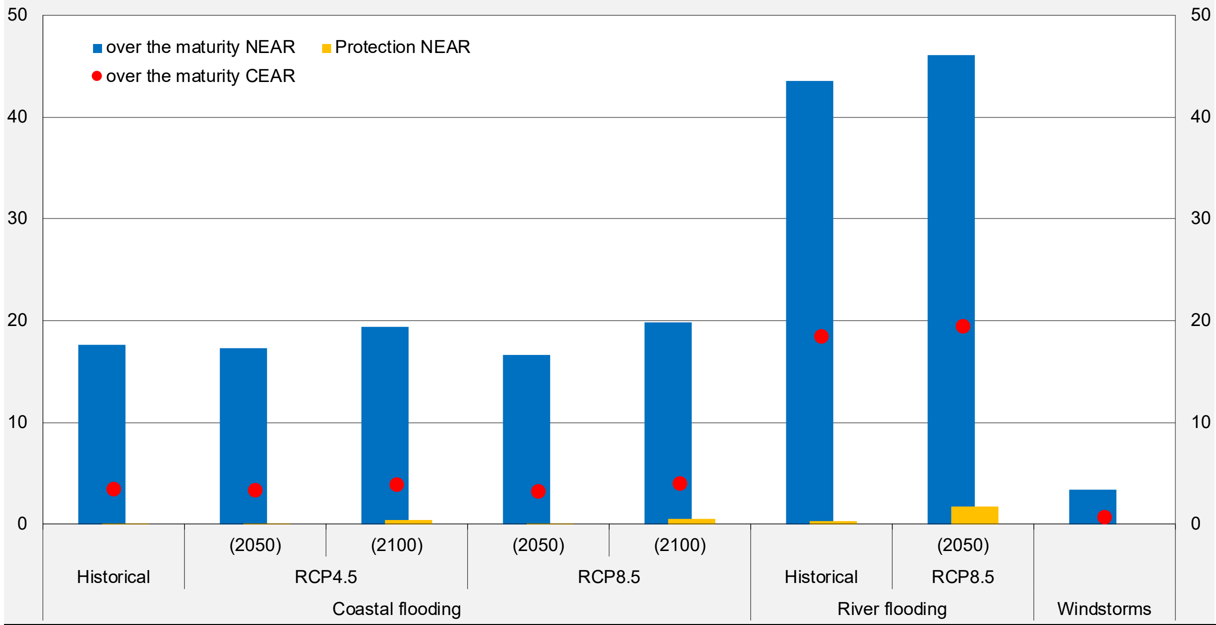
**Figure 8**

## Expected-loss indicators: NEAR and CEAR for loan portfolios of euro area banks

**(a) Percentages**



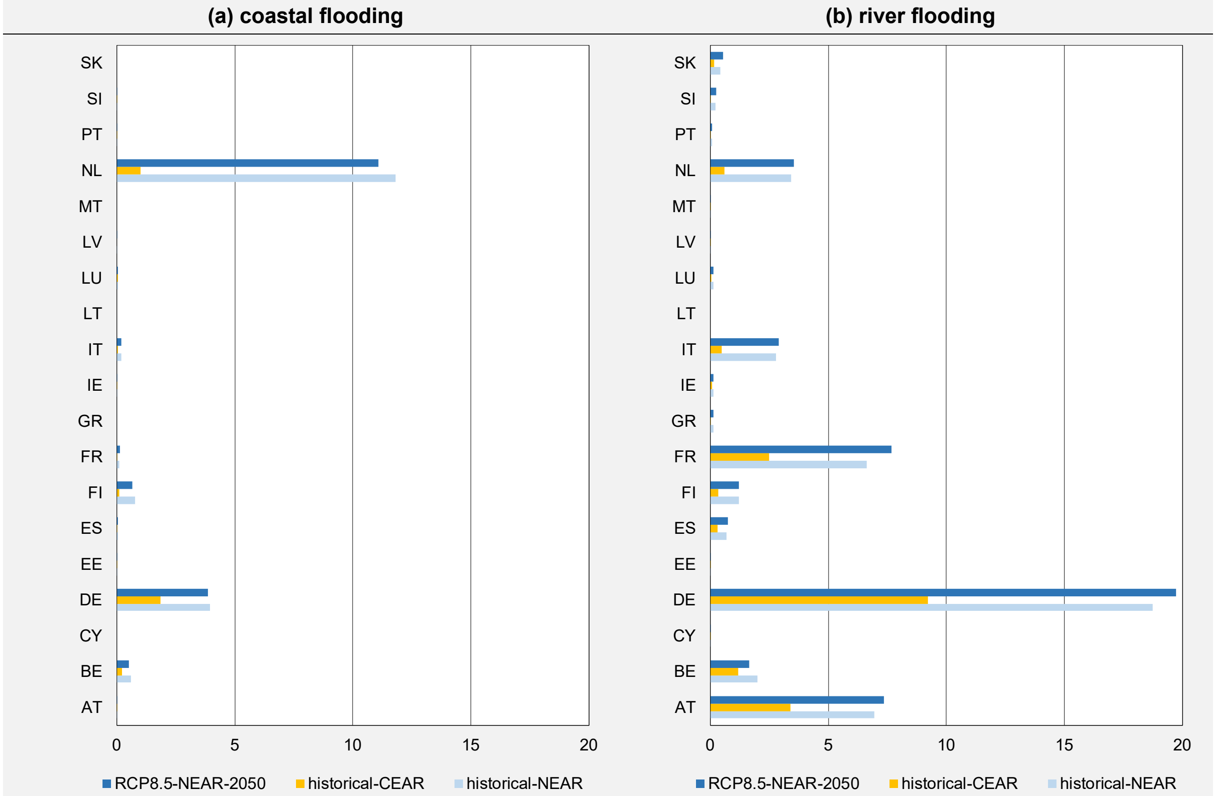

**(b) billions of euros**




Source: ESCB calculations based on AnaCredit, RIAD, and Delft University of Technology (TUD), for flood protection standards on Joint Research Centre (JRC), for windstorms on Copernicus.

Figure 9

**Expected-loss indicators: NEAR and CEAR for loan portfolios of euro area banks**
*(billions of euros)*




Source: ESCB calculations based on AnaCredit, RIAD, and Delft University of Technology (TUD), for flood protection standards on Joint Research Centre (JRC), for windstorms on Copernicus.

## 5. Discussion and next steps

In this Section we discuss some limitations and areas for improving the ECB analytical physical risk indicators.

**Insurances practices.** The ECB analytical indicators also account for national insurance practices. Insurance is essential in reducing the economic impact of natural disasters by mitigating both direct asset losses and indirect losses from business interruptions. However, assessing insurance coverage for such events is difficult due to limited data, particularly at the firm level. The indicators use two methods to estimate country-level hazard insurance coverage, based on the EIOPA protection gap dashboard. The first method, the historical share of insured losses, relies on data from the CATDAT and EM-DAT databases, which track economic and insured losses from natural catastrophes. However, both databases have quality and coverage limitations, and this method may not fully capture future shifts in insured losses. The second method estimates current insurance penetration, calculating the insured amount relative to the replacement value, and mainly depends on expert judgment from European Economic Area (EEA) supervisors. For the statistical climate indicators, the share of uninsured losses is determined by using historical losses and current insurance penetration as upper and lower bounds for net-of-insurance estimated losses. In computing the NEAR indicator, it is assumed that losses decrease proportionally with insurance coverage. The analysis still relies on several assumptions and would benefit from improved data on insurance coverage.

**Business units.** An additional area for improvement concerns the inclusion of data on business units. While the ECB-developed indicators are based on highly detailed information, they only use the address of a company's legal headquarters. This approach, consistent with the methodology of most existing indicators, overlooks the possibility that companies may have separate operational sites, with assets are often spread across the various business units which could face different catastrophic risks than those of the legal headquarters. To address this, the Expert Group that developed the indicators conducted national case studies to incorporate data from national business registers. These ad hoc analyses were essential, as such data is not always shareable. Currently, only France, Spain, and Italy have conducted national case studies.[17] The Italian case study shows that, although the addition of the information from the national business register does not significantly affect the overall risk indicator, it reveals notable regional differences that would not have been identified using the methodology originally employed by the ECB. [18]

**Geo-codification of the firms.** The precision of geocoding[19] is an important input for the physical risk assessment, and indeed highly depends on the quality of geo-refencing sources. The ECB analytical physical risk indicators refer to non-financial corporations which are geo-referenced with OpenStreetMap (OSM), the quality of which varies widely among countries. For Italy, for example, buildings' numbers are often not reported in OSM, potentially hindering an accurate identification of firms' location. In order to compute a measure of the geocoding error for OSM, robustness checks may be included by using a subset of points for which the exact location is known or by using another commercial data service (e.g. Loberto and Russo (2024) retrieve the coordinates of each firm using the Google Maps API and then they check their quality by using official data available on the Istat website).

**Interpretation of the loans' maturity.** NEAR and CEAR indicators take into account the maturity of the loans embedding the residual maturity in the expected loss of a loan. The assumption is that the longer the loan maturity, the higher the probability that an extreme event will hit a firm in the meantime. However, these indicators do not consider that the original loan amount usually decreases over time due the reimbursement plans bargained between lenders and borrowers. Therefore, NEAR and CEAR indicators may slightly overestimate the actual risk to financial intermediaries.

**Role of the collateral.** The formulation of the CEAR indicator assumes that the presence of the collateral reduces the expected losses if an extreme event hits the borrower. Nevertheless,

[17] In Italy, in particular, business register data cannot be shared. As a result, it was not possible to geolocate the operational site addresses, as this would have required sharing the data with the ECB. To overcome this issue, the postal code, which is available in the business register, was used instead. The analysis was therefore conducted at the postal code level. While using postal codes reduces precision compared to full addresses, integrating operational sites still provides a more accurate assessment of environmental risk than relying solely on legal headquarters.

[18] See also Cusano et al. (2025).

[19] Geocoding is the process of converting an address into geographic coordinates (latitude and longitude).

since physical assets, such as real estate and machinery, are included in the collateral pool, in the case of an extreme event the resale value of these assets could be potentially reset. This issue is only partially addressed by considering damage functions incorporating the hazard's intensity (e.g., water depth, wind speed), which reduce damages to a debtor's tangible fixed assets. Alternatively, the physical capital could be removed from the collateral pool in the computation of the CEAR indicator.

**Data availability.** Data gaps still remain a serious issue when it comes to climate risk assessment. The indicators presented above rely on data at the NUTS3 level for real estate pledged as collateral.[20] Obviously, more granular information could significantly enhance the accuracy of the assessment. Additionally, data on the ratio of tangible fixed assets to total assets is often incomplete and dependent on imputed values, which can lead to inaccuracies. The current damage functions focus solely on the direct destruction of physical property, neglecting secondary impacts like operational disruptions, increased costs, or damage across the supply chain. Challenges remain also in terms of climate data and modelling: even though the current indicators cover a wide range of hazards, these are treated as isolated events, failing to account for the compounding effects that can occur when multiple disasters happen simultaneously, thus exacerbating the damage. Finally, at least for the moment, climatologists are still not able to develop probabilistic hazard data for flash floods that map the inundation extent at Europe-wide scale. Therefore, none of the indicators presented above consider this risk which instead has recently proved to be extremely relevant in Italy and Spain.

## 6. Conclusions

The ECB analytical indicators cover several acute natural disasters (such as flooding, windstorms, wildfires or droughts) as well as chronic physical risks (heat and water stress). One of the main improvements of the latter release (in April 2024) with respect to the previous one (in January 2023) was the inclusion of projections aimed at considering the intensification of risks under different climate scenarios.

The indicators presented here, comparing historical data with future climate scenarios, highlight that financial institutions' exposure to physical risks is largely aligned with the geographical distribution of those risks. The analysis considers various climate-related hazards, including risks due to temperature, precipitation, drought, wildfires, water stress, and flooding. The results indicate that the risks to financial portfolios are expected to increase, especially under the pessimistic climate scenario. In particular, flood risks, although currently low, are expected to grow in the future. Flood defences currently mitigate a large portion of the impact, but they may not be sufficient to cope with more extreme future events, especially coastal flooding, which may require strengthening of protective infrastructures.

[20] NUTS (Nomenclature of Units for Territorial Statistics) levels are a classification system used by the European Union to divide regions for statistical purposes, ranging from large regions (NUTS 1) to smaller divisions like provinces or counties (NUTS 2 and NUTS 3).

The findings underscore the importance of adopting climate adaptation measures, such as strengthening flood defences and incorporating climate risk into portfolio management, to reduce future losses and ensure the resilience of the financial system.

Indicators such as NEAR (Normalized Exposure at Risk) and CEAR (Collateral-Adjusted Exposure at Risk) reveal that, while flood defences significantly reduce expected losses at present, their effectiveness could decrease as climate change progresses, particularly for coastal flooding. Collateral, which reflects national practices related to loans and pledged assets, plays a crucial role in mitigating risks. For example, for river flooding, collateral reduces expected losses by 58 percent across the euro area, while for coastal flooding and windstorms, this reduction is over 80 percent.

Overall, the Italian financial system faces higher risks from water stress compared to other euro area countries. Instead, the evidence on drought and flood risk indicators shows that the exposure of the Italian financial system is, overall, in line with the euro area, both in the baseline scenario and considering IPCC projections for 2040, assuming constant banks portfolios. The wildfire risk is higher in Italy compared to the euro area but remains at generally low levels.

Despite the improvements in the latter release of the indicators, as highlighted above several shortcomings persist regarding the hazards considered (co-occurring hazards are still not modelled), the availability, accuracy and granularity of the data underlying the indicators, the assumptions made, and the narrow scope of the analysis, which focuses solely on the direct destruction of physical assets, while overlooking secondary effects and other sources of potential underestimation. Addressing such shortcoming is part of our future research agenda.

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