Sustainable Resilience: Linking Climate-Related Economic Losses to Progress on the Sustainable Development Goals in Europe

by *Oksana Liashenko*[*], *Olena Mykhajlovska*[**], *Pavlo Halimon*[***], *Sergey Selyutin*[****], *Tetiana Shestakovska*[*****]

Abstract

The authors investigate whether progress on the Sustainable Development Goals (SDGs) is associated with the magnitude of climate-related economic losses across European countries. Drawing on typological classifications, disaggregated SDG indicators, and Granger causality tests, the study explores dynamic interactions between development performance and climate-related vulnerability. While no stable correlation emerges across all cases, a pattern of reactive adaptation is observed in high-loss countries, where improvements in SDG 13 often follow damaging events. These findings underscore the importance of aligning development policy with climate resilience frameworks and highlight the need for stronger integration between long-term sustainability planning and risk governance strategies.
Keywords: Sustainable Development Goals, Climate Losses, Europe, Resilience, Granger Causality, Policy Integration.

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[*] Loughborough Business School, Loughborough University, Epinal Way, Loughborough, LE11 3TU, UK, e-mail: o.liashenko@lboro.ac.uk.
[**] Higher educational institution «University of Future Transformation», Remisnycha Str., 28 Chernihiv, Ukraine.
[***] National Academy of Agrarian Sciences of Ukraine, Mykhaila Omelianovycha-Pavlenka Str., 9, Kyiv, Ukraine.
[****] Higher educational institution «University of Future Transformation», Remisnycha Str., 28 Chernihiv, Ukraine.
[*****] Higher educational institution «University of Future Transformation», Remisnycha Str., 28 Chernihiv, Ukraine.

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Introduction

Climate-related economic losses pose an increasingly urgent challenge for European countries. The increasing intensity and frequency of extreme weather events, such as floods, heatwaves, droughts, and storms, have resulted in substantial financial burdens. According to the European Environment Agency (EEA), cumulative damages across the EU have surpassed €650 billion between 1980 and 2023. These economic losses not only disrupt national economies and infrastructure systems but also place considerable strain on the long-term achievement of the Sustainable Development Goals (SDGs), particularly Goals 9 (Industry, Innovation and Infrastructure), 11 (Sustainable Cities and Communities), and 13 (Climate Action).

Despite a growing body of research on climate-related hazards and sustainable development, few studies have systematically examined the empirical relationship between these two concepts. Much of the existing literature treats sustainable development and climate vulnerability as parallel but separate domains. Consequently, little is known about whether progress in SDG implementation leads to a measurable reduction in climate-related economic losses, or whether these losses, conversely, catalyse development responses.

This study frames this intersection through the lens of sustainable resilience. This concept refers to a country's ability to absorb, adapt to, and recover from climate-related shocks without compromising its long-term development objectives. Unlike short-term or reactive adaptation, sustainable resilience emphasises the alignment of resilience strategies with structural development objectives, including institutional strength, urban planning, and infrastructure investment. It reflects the idea that genuine resilience must be development-compatible, forward-looking, and durable in the face of compounding crises.

Addressing the existing analytical gap, this article investigates whether sustainable development and vulnerability reduction co-evolve in a statistically meaningful manner across European countries. The core aim is to explore the potential for structural linkages or feedback effects between SDG performance and economic climate losses. Specifically, we assess both the directionality and long-term association of key indicators, testing whether countries that perform strongly on relevant SDGs are also more resilient to economic losses from climate extremes.

To operationalise this objective, we develop a typology of EU countries based on their average SDG scores and cumulative climate-related losses. This typology enables a comparative assessment of development-resilience profiles. We then apply time-series methods, including Engle–Granger cointegration and Granger causality tests, to evaluate the dynamic interplay between SDG progress (with a focus on Goals 9, 11, and 13) and vulnerability outcomes over the period 2000–2023.

The following research questions guide the study:

1. Is there a correlation between national SDG performance and the scale of climate-related economic losses?
2. Do countries with structurally high losses tend to lag in sustainable development outcomes?
3. Can progress on selected SDGs, particularly those related to infrastructure and climate action, reduce future economic vulnerability?
4. Do any countries demonstrate resilient development trajectories—combining high SDG performance with low climate-related losses?
5. Is there evidence of temporal causality, suggesting that improvements in development indicators follow or precede climate loss events?

By combining typological analysis with dynamic statistical modelling, this study contributes new evidence on the links between climate vulnerability and sustainable development. It further supports the case for integrated governance, where risk reduction and development planning are treated as mutually reinforcing, rather than separate, policy domains.

Literature Review

The increasing frequency and severity of climate-related disasters across Europe have brought economic losses to the forefront of climate risk governance. According to the European Environment Agency (EEA), weather- and climate-related events caused over €650 billion in damages between 1980 and 2020 across EEA countries, with losses exhibiting marked spatial and temporal concentration.

The role of anthropogenic factors in shaping these outcomes remains a key subject of scholarly debate. Bouwer (2011) emphasised that socio-economic development and asset exposure are more decisive drivers of rising losses than hazard frequency alone. Supporting this view, Formetta and Feyen (2019) demonstrated that the global decline in vulnerability to climate-related hazards is significantly moderated by social indicators such as income levels, governance quality, and institutional strength. Similarly, Forzieri et al. (2018), using modelling of future climate extremes in Europe, concluded that without adaptation, losses to critical infrastructure may rise substantially. In contrast, investment in resilience offers a significant reduction in projected damages.

At the European scale, several studies (e.g., De Groeve et al., 2013; Paprotny et al., 2018) have examined cross-national loss distributions through geospatial datasets and statistical damage models. A recurring insight is the presence of structural asymmetries: economic burdens from climate-related events are heavily concentrated in a few Western and Central European countries. In contrast, others experience minimal or irregular losses.

In parallel, the literature addressing the Sustainable Development Goals (SDGs) has explored the role of development pathways in fostering resilience. Sachs et al. (2022) and the annual SDG Index published by the SDSN highlight disparities across EU member states, particularly in relation to Goals 9 (Industry, Innovation, and Infrastructure), 11 (Sustainable Cities and Communities), and 13 (Climate Action). These goals directly relate to adaptive capacity and disaster risk mitigation, yet their long-term correlation with economic losses remains insufficiently examined.

Recent work increasingly applies multivariate typologies to group countries by their developmental performance, arguing that such classifications can reveal latent vulnerabilities in the face of environmental shocks. Liashenko et al. (2024) propose a multidimensional framework distinguishing governance-driven from development-driven patterns of resilience across nations. Likewise, Liashenko and Dluhopolskyi (2024) investigate how welfare preferences and digital transformation trajectories intersect with sustainability outcomes, potentially shaping national resilience profiles.

However, only a handful of empirical studies have attempted to link development indicators with climate impact metrics directly. Capasso et al. (2020) suggest that stronger governance and financial resilience (as captured in SDGs 16 and 17) can help cushion the socio-economic effects of disasters. Gualandri et al. (2023) introduce the concept of "climate-financial transmission channels," describing how physical climate shocks may influence development through mechanisms such as credit constraints, infrastructure delays, or insurance retreat.

The emerging literature is also turning towards structural typologies and systems-based modelling to understand these dynamics better. Vanhala and Paterson (2021) advocate for incorporating macro-financial risk metrics into SDG monitoring frameworks, recommending typological approaches to identify critical contrasts, such as between economically advanced but climate-vulnerable states, and countries with comparatively low development scores yet high resilience. Nonetheless, these typologies remain underdeveloped empirically.

Furthermore, as the PESETA IV project highlights (Ciscar et al., 2018), there remains a lack of harmonised methodologies within the EU for analysing development and climate risk together. Most assessments treat these dimensions separately, neglecting to examine whether they move jointly, diverge, or demonstrate structural co-movement (e.g., cointegration). This analytical gap is particularly pertinent as the climate-development nexus becomes more central to European policy frameworks, notably the European Green Deal and the EU Climate Adaptation Strategy.

This study aims to address this gap by developing a new typology of European countries based on their performance in achieving the SDGs and cumulative climate-related losses. Particular attention is paid to Goals 9, 11, and 13, which concern economic vulnerability. Methodologically, the study introduces a novel statistical approach by testing for both association and long-term co-movement (cointegration) between climate-related losses and SDG indicators—an approach that has not yet been applied in the EU context.

In Europe, the intersection of climate-related economic losses and sustainable development goals remains an evolving field of research, particularly as nations strive to balance ecological integrity with socioeconomic progress. Central to this discussion is the European Green Deal (EGD), which aims to mainstream sustainability across key sectors, including agriculture. Here, attention to land and soil management is increasingly recognised as an essential – albeit often understated – component of ecological health and long-term climate resilience (Montanarella, 2020).

The effectiveness of EU-level policies in shaping progress toward the SDGs has also been critically examined. Scown and Nicholas (2020), for instance, suggest that the Common Agricultural Policy (CAP) may inadvertently hinder progress towards global sustainability targets, calling for a renewed policy performance framework better aligned with the 2030 Agenda. Beverelli et al. (2020) emphasise the importance of an integrated approach to achieving the SDGs – one that encompasses trade, investment, and policy evaluation across both environmental and social domains. Within this context, multinational enterprises are recognised as key actors, capable of advancing local sustainability efforts in line with global commitments (Eang et al., 2022; Kolk et al., 2017).

Advancing climate resilience is also considered crucial for mitigating the economic impact of environmental disruptions. Badolo (2024) outlines a governance framework designed to enhance local adaptive capacity through innovative strategies and metrics. Complementing this, Shaw and Maythorne (2012) emphasise the need for policy frameworks that combine short-term recovery with long-term transformational objectives. This is particularly relevant in the agricultural sector, where increasing climate risks demand adaptive practices that safeguard both economic stability and food systems (Aggarwal et al., 2018).

The societal dimension of climate-induced losses further necessitates inclusive, community-oriented responses. Franco and Tracey (2019) argue for community capacity-building aligned with selected SDGs to foster local resilience and ownership of development initiatives. Havea et al. (2018) similarly underscore the importance of integrating community perspectives into policymaking to ensure accountability and efficacy in achieving SDG targets.

In sum, this literature review highlights the intricate connections between climate resilience, economic losses, and progress toward the SDGs within the European context. Sustaining both ecological and socio-economic systems in the face of growing environmental stress requires cohesive, cross-sectoral strategies that integrate agricultural practices, community engagement, and private-sector contributions, all guided by the ambitions of the European Green Deal and the 2030 Agenda.

Methods

This study employs a structured quantitative approach to investigate the relationship between climate-related economic losses and advancements in sustainable development across European nations. The focus is on identifying time-based trends, structural differences, and possible connections between vulnerability and SDG progress.

Data Sources

Climate-related economic losses were sourced from the European Environment Agency (EEA, 2025) dataset on damage caused by weather and climate-related events, expressed in inflation-adjusted euros. This dataset spans the period from 1980 to 2023, enabling consistent intertemporal and cross-country comparisons. Data on Sustainable Development Goals (SDGs) performance were obtained from the UN Sustainable Development Solutions Network (SDSN), using annual national SDG Index scores for the years 2000-2023.

Analytical Procedure

The analysis proceeded in five stages:

1. Descriptive Profiling: Time series of economic losses were analysed across EU27 countries to identify temporal peaks and spatial disparities. Summary statistics and bar plots were used to characterise average and cumulative losses per country and region.
2. Typology Construction: Countries were classified into four quadrants based on their average SDG Index score and cumulative climate-related losses: High SDG/High Loss; High SDG/Low Loss; Low SDG/High Loss; Low SDG/Low Loss. This typology served as a comparative framework for subsequent group-based analysis.
3. Disaggregated SDG Analysis: To understand the thematic drivers of resilience, SDG performance was disaggregated into three key areas: Goal 9 (Infrastructure), Goal 11 (Sustainable Cities), and Goal 13 (Climate Action). Within each typological group, annual averages were calculated and normalised (Min-Max scaling) to produce multi-panel time-series visualisations.
4. Correlation and Cointegration Testing: Pearson correlation coefficients were computed between economic losses and each SDG goal within each group. Additionally, Engle–Granger cointegration tests were conducted to examine the presence of stable long-term relationships between SDG progress and loss levels. The absence of cointegration was interpreted as a structural decoupling between policy trajectories and vulnerability exposure.
5. Granger Causality Modelling: For the group exhibiting both high losses and low SDG performance, Granger causality tests were conducted on annual average time series (2000-2023) to evaluate whether economic losses at time t-1 significantly predicted SDG 13 outcomes at time *t*. Vector autoregression (VAR) models were used to estimate the lag structures and directional dependencies. A statistically significant effect ($p < 0.10$) was found at a 1-year lag, suggesting the existence of reactive adaptation patterns where policy engagement increases in response to prior climate damages.

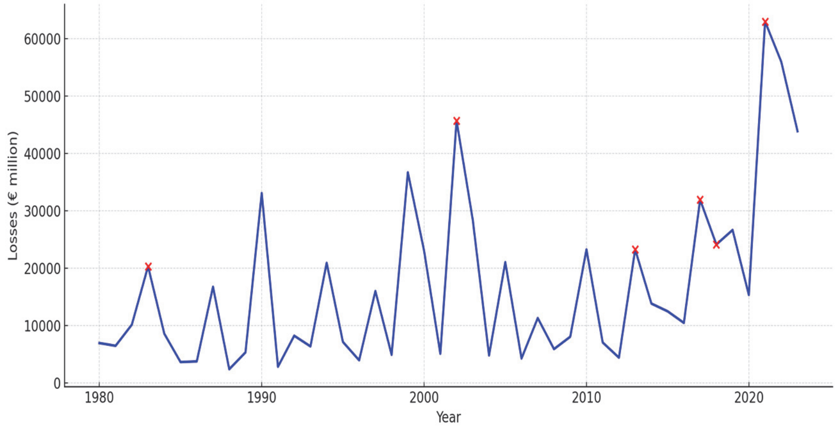
All analyses were performed using Python libraries, ensuring replicability of results and transparent processing.

Results

Economic losses resulting from climate- and weather-related extreme events across European countries show significant variability over time and between regions. The dataset spans the period from 1980 to 2023, highlighting both long-term trends and instances of sharp increases in losses associated with extreme weather events.

At the European Union level (comprising 27 countries), the highest economic loss was recorded in 2021, exceeding €62.9 billion – a figure that far surpasses the annual average of previous decades. Other peak years include 1983, 2002, 2013, 2017, and 2018, with losses ranging from €20 to €30 billion. These spikes reflect either an increase in the severity or frequency of damaging climate events.

Figure 1 - Annual climate-related economic losses in the EU27, 1980-2023.

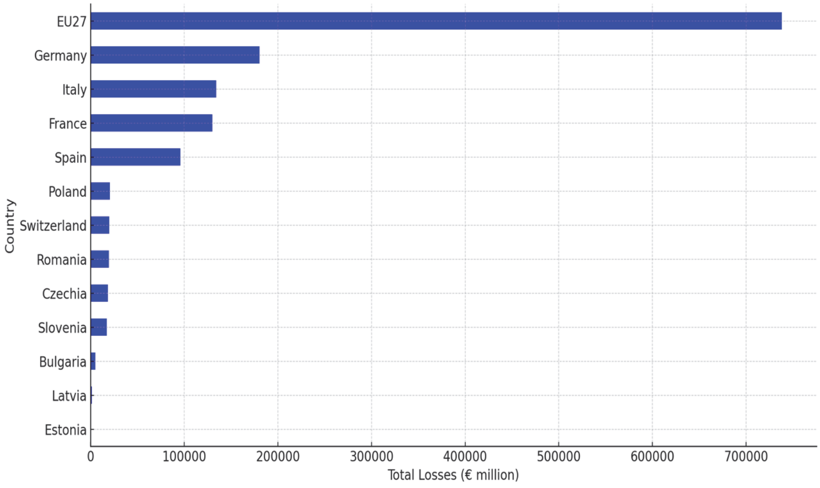


Marked peaks indicate years with the highest reported losses, particularly 2021, which recorded more than €62.9 billion in damages.
Source: EEA.

At the national level, there is considerable disparity (Fig. 2). Countries such as Germany, Italy, France, and Spain consistently experience substantial economic losses. In contrast, others, including Bulgaria, Latvia, and Estonia, report little to no losses over extended periods. This disparity suggests both differences in exposure and the resilience of national infrastructure and response systems.

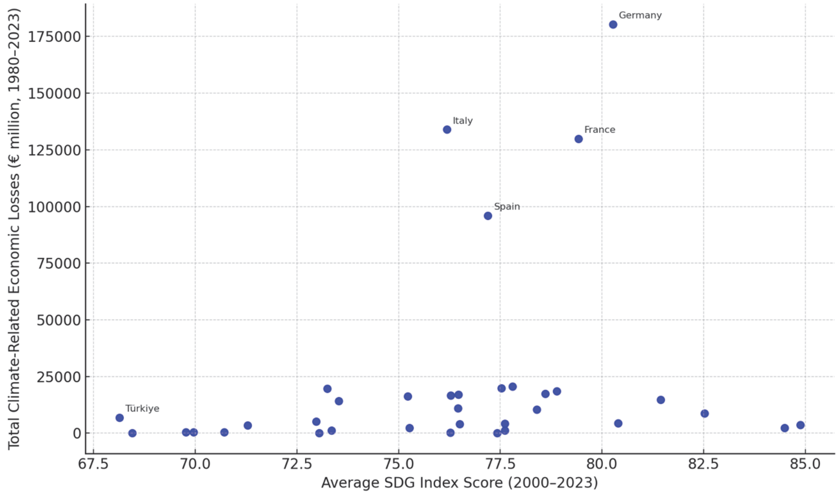
To explore the potential relationship between sustainable development progress and vulnerability to climate-related damages, we compare countries' average SDG Index scores with their cumulative economic losses. The following figure illustrates this relationship for European countries over the periods 1980-2023 (losses) and 2000-2023 (SDG performance).

Figure 2 - Cumulative climate-related economic losses by country in Europe, 1980-2023.



Source: EEA.

Figure 3 - Relationship between average SDG Index Score (2000-2023) and cumulative climate-related economic losses (1980-2023) in European countries.

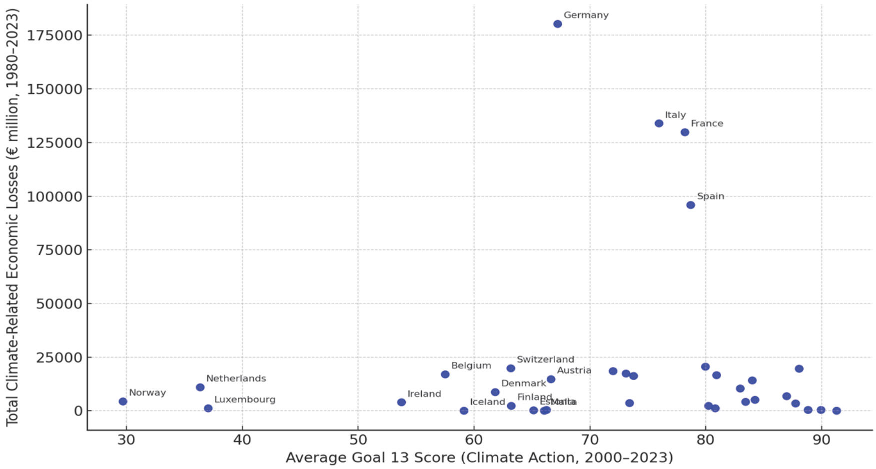


Source: authors' calculations on EEA, SDG UN data.

As shown in the figure above, countries with the highest losses, such as Germany, France, Italy, and Spain, tend to have relatively high SDG performance; however, no clear linear association is observed overall.

To better understand whether national progress on climate action is associated with resilience to economic damages, we compare countries' average scores for SDG Goal 13 (Climate Action) with their total reported losses. Goal 13 includes indicators on climate policies, disaster risk reduction, and adaptation planning, making it a relevant proxy for national climate preparedness. Figure 4 examines whether stronger national performance in climate action is correlated with reduced economic vulnerability.

Figure 4 - Relationship between average SDG Goal 13 score (2000-2023) and cumulative climate-related economic losses (1980–2023) in European countries



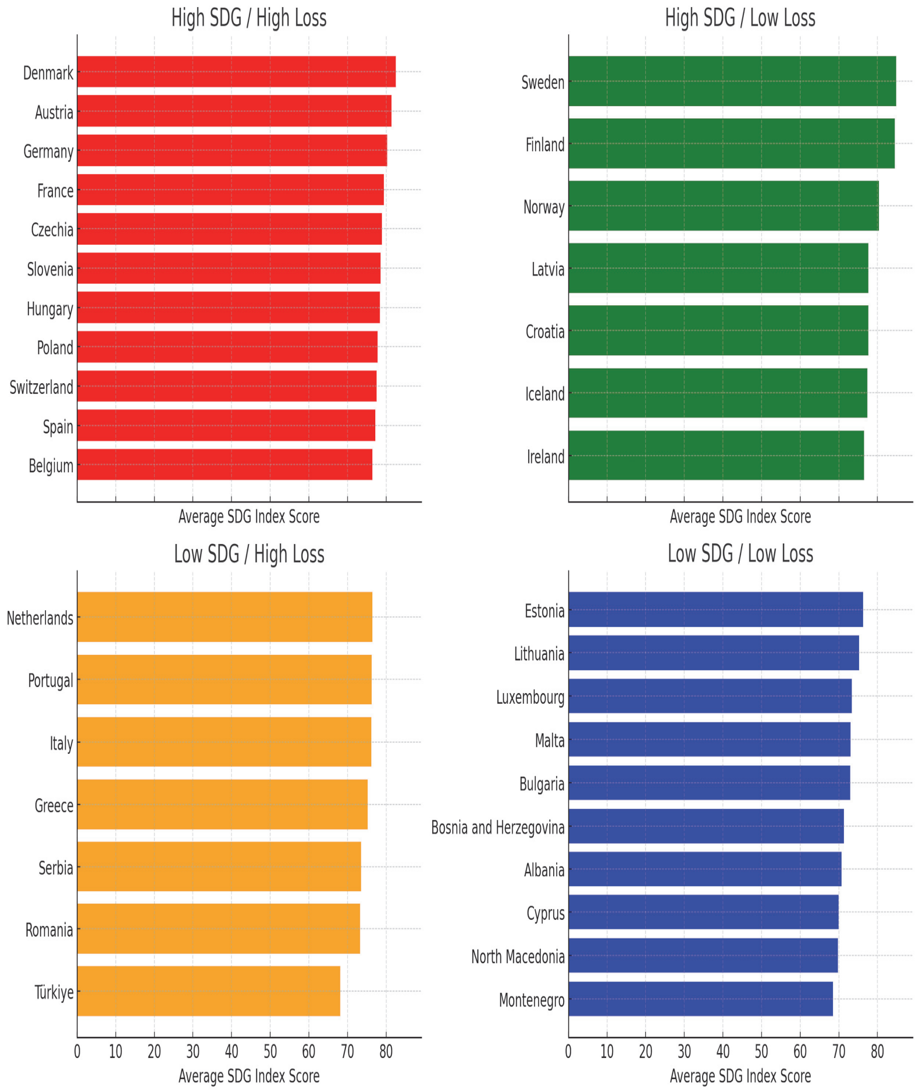
Source: authors' calculations on EEA, SDG UN data.

While some countries with higher Goal 13 scores experience lower losses, others, including Germany, France, and Italy, show both high preparedness and high levels of damage. This suggests that climate action progress alone may not be sufficient to offset structural exposure to extreme events, or that it reflects post-event policy improvement rather than pre-event prevention.

To further explore the typology of national resilience patterns, countries were categorised into four groups based on their average SDG Index Score (2000–2023) and total climate-related economic losses (1980–2023). This classification highlights the intersection of sustainable development performance and vulnerability to climate shocks.

Countries are divided into four groups: (1) High SDG / High Loss, (2) High SDG / Low Loss, (3) Low SDG / High Loss, and (4) Low SDG / Low Loss. Each panel displays the average SDG Index Score for each country within its respective typology.

Figure 5 - Typology of European countries based on SDG Index Score and climate-related economic losses



Source: authors' calculations on EEA, SDG UN data.

The visualisation shows that some countries, such as Slovenia and the Czech Republic, combine strong performance in sustainable development with relatively low exposure to climate-related damages. Others, including Germany, France, and Italy, appear in the High SDG/High Loss quadrant, indicating strong institutional development but continued structural vulnerability. This typology provides a foundation for identifying best practices and potential resilience gaps across Europe.

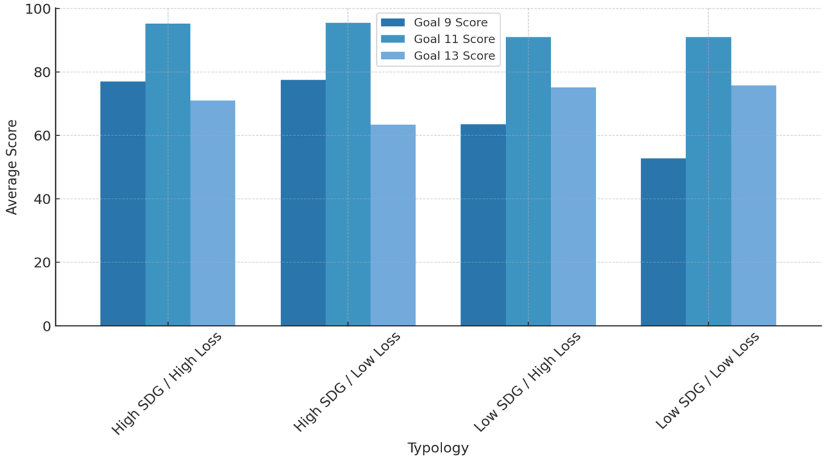
Building on the typological classification of European countries based on their sustainable development performance and exposure to climate-related economic losses, we proceed to a more focused exploration of national resilience profiles. The four identified groups – High SDG/High Loss, High SDG/Low Loss, Low SDG/High Loss, and Low SDG/Low Loss – serve as a conceptual lens for interpreting the interplay between development strategies and structural climate vulnerability.

To gain deeper insight into the characteristics that may contribute to these differences, we disaggregate SDG performance within each typology group. The analysis focuses on three goals that are particularly relevant to climate-related damages:

- Goal 9 (Industry, Innovation and Infrastructure), which reflects investment in resilient infrastructure and sustainable industrialisation;
- Goal 11 (Sustainable Cities and Communities), which captures urban resilience and risk-sensitive planning;
- Goal 13 (Climate Action) represents direct efforts to mitigate and adapt to climate change.

By comparing average scores across these goals within each group, we aim to identify patterns of strength or deficiency that may help explain variations in exposure and loss.

Figure 6 - Average SDG scores for Goals 9 (Infrastructure), 11 (Sustainable Cities), and 13 (Climate Action) across the four resilience typology groups



Source: Authors' calculations based on EEA and UN SDG data.

Figure 6 highlights meaningful contrasts between typology groups. Countries in the High SDG/Low Loss group demonstrate high average scores across all three goals – particularly for infrastructure and urban sustainability – suggesting that investments in resilient systems may play a role in reducing exposure to climate-related losses. However, their relatively lower scores for Goal 13 (Climate Action) suggest that low losses may reduce political urgency for implementing climate policy.

In contrast, the Low SDG/High Loss group exhibits weaker infrastructure and city-level preparedness, yet shows relatively high scores for Goal 13. This pattern may reflect reactive policy-making in response to repeated climate shocks, rather than pre-emptive resilience planning.

Interestingly, the Low SDG/Low Loss group exhibits the lowest capacity in infrastructure and urban resilience, but surprisingly high scores for climate action. This could indicate symbolic or aspirational commitments that are not yet backed by structural development. Meanwhile, the High SDG/High Loss group combines strong development with continued high exposure, likely due to geographic or economic factors beyond policy control.

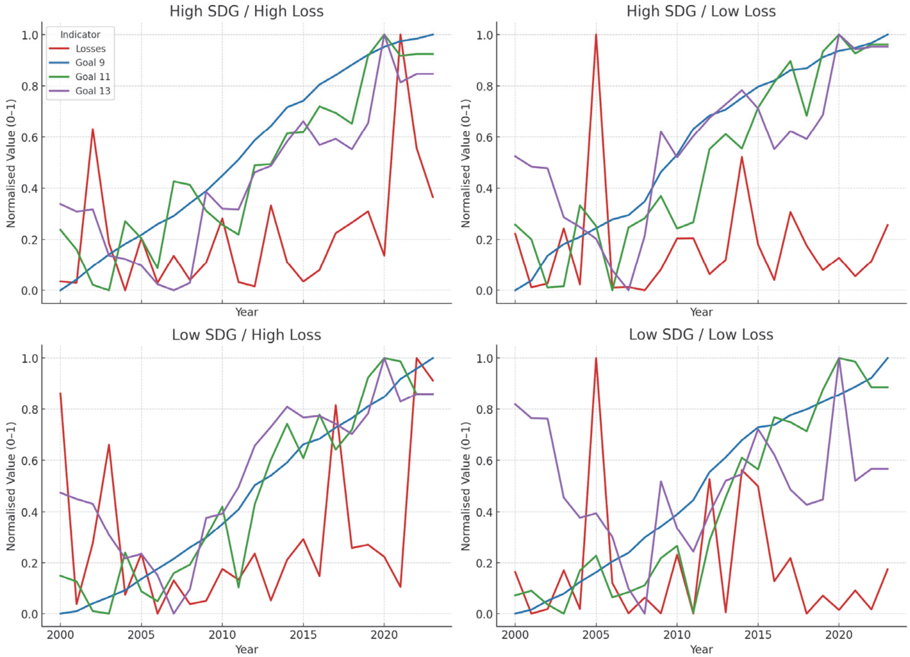
These patterns underscore the importance of targeted infrastructure and urban development, as well as context-specific climate strategies, in shaping the resilience outcomes of countries.

To better understand the temporal dynamics within each resilience typology, we examined the year-on-year evolution of climate-related economic losses. We selected SDG indicators (Goals 9, 11, and 13) for the period 2000-2023. Each indicator was normalised on a 0-1 scale to allow for comparison across metrics of different magnitudes. The resulting trends (Fig. 7) highlight the internal trajectories of resilience-building efforts, particularly in terms of the occurrence and intensity of economic losses.

Each panel on Fig. 7 shows standardised annual trends within one typology group, highlighting patterns of adaptation, infrastructure development, and loss exposure.

The visualisation reveals distinct group-specific patterns. In the High SDG/High Loss group, infrastructure and urban resilience have steadily improved; however, economic losses remain volatile, suggesting an exposure-driven vulnerability that persists despite development progress. The High SDG/Low Loss group shows stable or improving performance across all indicators with relatively low and stable loss levels, reflecting potentially effective long-term resilience strategies.

Figure 7 - Normalised trajectories (2000-2023) of climate-related losses and SDG Goals 9, 11, and 13 across the four typology groups



Source: Authors' calculations based on EEA and UN SDG data.

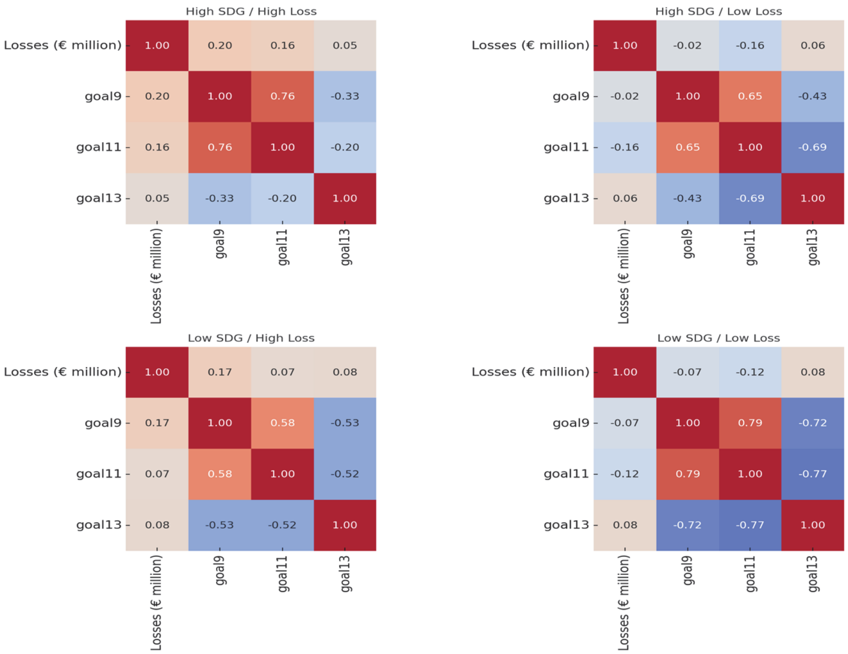
In contrast, the Low SDG/High Loss group exhibits fluctuations in both policy indicators and losses, with increases in Goal 13 performance often appearing reactive to prior loss spikes. The Low SDG/Low Loss group exhibits modest development trajectories with relatively low losses; however, the absence of upward SDG trends may indicate underinvestment or latent exposure risks.

These intra-group dynamics underscore the notion that climate resilience is a dynamic concept, shaped not only by structural development but also by the timing, frequency, and nature of climate impacts.

To assess whether patterns of sustainable development performance are statistically associated with climate-related economic losses, we computed Pearson correlation coefficients between annual loss values and selected SDG indicators (Goals 9, 11, and 13) within each typology group.

Fig. 8 presents the correlations for each group. Overall, the associations are weak to moderate, but specific patterns emerge. In the High SDG / High Loss group, we observe a slight positive correlation between losses and infrastructure development ($r = +0.20$), suggesting that improvements in Goal 9 may not be sufficient to mitigate loss exposure, possibly due to the high baseline value of existing infrastructure at risk. The relationship with Goal 11 (urban resilience) and Goal 13 (climate action) remains weak.

Figure 8 - Correlation matrices of climate-related economic losses and SDG Goals 9, 11, and 13, disaggregated by typology group



Source: Authors' calculations based on EEA and UN SDG data.

By contrast, the High SDG / Low Loss group shows a negative correlation between losses and Goal 11 (r = – 0.16), suggesting that investments in sustainable cities may be associated with reduced vulnerability. This group also exhibits a near-zero correlation with Goal 9, which may indicate a plateau in infrastructure expansion or a decoupling from exposure levels.

Interestingly, in the Low SDG / High Loss group, all correlations are slightly positive – especially with Goal 9 (r = + 0.17) – possibly reflecting a reactive development trajectory where infrastructure investment follows damages rather than precedes them.

The Low SDG/Low Loss group exhibits weak and mostly negative correlations, which may indicate either a low dynamic range in the data or latent risk factors not captured by the SDG indicators.

These patterns suggest that while higher SDG performance is not linearly associated with lower losses, targeted investments – especially those focused on Goal 11 – may play a modest role in reducing exposure. Further causal analysis would be required to confirm such relationships.

To assess whether long-term structural linkages exist between progress in sustainable development and climate-related economic losses, we conducted Engle-Granger cointegration tests for each typology group. These tests evaluate whether two non-stationary time series maintain a stable equilibrium relationship over time. Specifically, we tested for cointegration between annual losses and each of the three selected SDG indicators: Goal 9 (Infrastructure), Goal 11 (Sustainable Cities), and Goal 13 (Climate Action), using group-level averages from 2000 to 2023.

Across all four typology groups, the test statistics failed to reject the null hypothesis of no cointegration at standard significance levels ($p > 0.05$). Even in the High SDG / Low Loss group – which exhibited the closest fit – the lowest p-values hovered around 0.29 to 0.38, indicating no statistically significant long-term equilibrium relationships.

Table 1 - Engle–Granger Cointegration Test Results (2000-2023)

Group	*Losses ~ Goal9*	*Losses ~ Goal11*	*Losses ~ Goal 13*
High SDG/High Loss	0.93	0.95	0.45
Low SDG/High Loss	0.53	0.45	0.60
High SDG/Low Loss	0.38	0.29	0.31
Low SDG/Low Loss	0.90	0.90	0.90

These results suggest that, while SDG performance and climate-related losses may evolve simultaneously, they do not appear to be structurally or predictively linked over time. In practical terms, this means that development trajectories in areas like infrastructure and climate policy may not consistently translate into measurable reductions in losses, or vice versa. This lack of cointegration supports the idea that the interaction between development and resilience is dynamic, contingent, and shaped by both short-term shocks and long-term planning.

To investigate whether climate-related economic losses precede improvements in national climate action (as measured by SDG 13), we applied the Granger causality test to the average time series data for the *Low SDG / High Loss* group (comprising Bulgaria, Czechia, Greece, Croatia, Hungary, Poland, Portugal, Romania, Slovakia, and Slovenia). This group showed the most volatile loss patterns and dynamic trends in SDG 13 scores.

We constructed a panel of yearly averages (2000-2023) for two key indicators: Losses, which represent aggregated annual climate-related economic losses (€ million), and SDG 13, the climate action index (scale 0–

100). We then computed a 1-year lag of losses to test whether past damage levels Granger-cause improvements in climate policy.

To explore potential feedback dynamics between sustainable development and climate vulnerability, the figure below presents the average annual SDG 13 (Climate Action) scores alongside one-year lagged economic losses for each of the four typology groups. This comparison allows an initial visual assessment of whether policy improvements tend to follow (or precede) years of significant climate-related damages.

Figure 9 - Average SDG 13 Index Scores and One-Year Lagged Climate-Related Economic Losses by Typology Group (2000-2023)

Across the typologies, notable differences in temporal alignment can be observed. In the Low SDG/High Loss group, peaks in economic losses are frequently followed by subsequent increases in SDG 13, indicating reactive adaptation dynamics. Conversely, in the High SDG/ Low Loss group, both indicators remain relatively stable, suggesting more consistent policy trajectories. These patterns reinforce the findings from the Granger causality tests and imply the need for more anticipatory governance mechanisms in highly exposed states.

To further explore potential causal mechanisms between sustainable development trajectories and climate-related losses, we applied the Granger causality test (lags 1-3) and estimated Vector Autoregression (VAR) models for each typological group. These analyses aim to determine whether past climate losses predict subsequent changes in SDG 13 (Climate Action) scores and vice versa.

Granger Causality Test Results (see Table 2) reveal a statistically significant effect only in the Low SDG/High Loss group at lag 1 (p = 0.098), suggesting that previous-year losses Granger-cause increases in SDG 13 scores. This supports the hypothesis that these countries often pursue climate action reactively, rather than preventively, in response to disaster shocks. For other groups, p-values remain above conventional significance thresholds, indicating no consistent temporal causality.

Table 2 - Granger Causality Test Results (F-statistics and p-values)

Group	*Lag 1 F-stat*	*p-value*	*Lag 2 F-stat*	*p-value*	*Lag 3 F-stat*	*p-value*
High SDG / High Loss	2.415	0.154	1.212	0.381	0.874	0.501
High SDG / Low Loss	0.796	0.388	0.936	0.420	0.932	0.476
Low SDG / Low Loss	2.228	0.170	1.322	0.348	1.201	0.398
Low SDG / High Loss	3.235	0.098	1.602	0.274	1.498	0.302

To reinforce these findings, we also implemented VAR models (lag = 1) and extracted coefficient matrices (Table 3). The *Low SDG / High Loss* group again shows a small but directionally meaningful coefficient for Lagged Losses → SDG 13 (– 0.00026), consistent with the feedback logic. Across other groups, coefficients remain statistically and substantively weak, with minor or adverse effects and no clear patterns.

Table 3 - VAR Model Coefficients (Lag = 1)

Group	$SDG13_{(t-1)} \rightarrow SDG13_t$	$Losses_{(t-1)} \rightarrow SDG13_t$	$SDG13_{(t-1)} \rightarrow Losses_t$	$Losses_{(t-1)} \rightarrow Losses_t$
High SDG/High Loss	0.9434	– 0.000021	326.55	– 0.0343
High SDG/Low Loss	0.9040	– 0.00496	0.616	– 0.2055
Low SDG/Low Loss	0.4737	0.000234	– 3.85	– 0.1015
Low SDG/High Loss	0.972	– 0.00026	146.32	0.0164

These results provide quantitative support for the hypothesis that post-disaster increases in policy activity (SDG 13) occur primarily in structurally vulnerable contexts**.** While the effect sizes are modest due to data scale, their directionality and statistical support at short lags suggest the presence of a reactive adaptation pattern rather than proactive resilience planning.

Discussion

This study set out to investigate whether countries' performance on selected Sustainable Development Goals (SDGs) is meaningfully linked to their exposure to climate-related economic losses. By combining descriptive, typological, and time-series approaches, it advances the empirical understanding of how development trajectories interact with vulnerability to climate shocks across Europe.

To the first research question, the results reveal a weak or inconsistent correlation between overall SDG progress and climate-related losses. High-SDG countries such as Germany, France, and Italy continue to register some of the most significant economic damages. This suggests that structural exposure – such as urbanisation intensity, economic concentration, or geographic location – may outweigh development-based resilience in terms of actual damage levels. In other words, high SDG performance does not automatically translate into lower climate vulnerability.

Regarding the second question, our typological and temporal analysis indicates that countries with persistently high economic losses are not necessarily underperformers in terms of SDG implementation. However, these countries tend to exhibit a reactive pattern in their policy engagement. This is particularly evident in SDG 13 (Climate Action), where countries in the Low SDG / High Loss group show increased policy scores following, rather than preceding, significant climate-related damages.

This temporal insight is reinforced by the results of the Granger causality tests, which provide statistically significant evidence of short-term lag effects. Specifically, in the Low SDG / High Loss group, economic damages Granger-cause improvements in SDG 13 scores at a one-year lag ($p < 0.10$). This suggests the presence of reverse feedback mechanisms, whereby policy attention and institutional adaptation follow shocks rather than proactively prevent them. By contrast, no such feedback loops were found in the Low SDG/Low Loss group, where both exposure and response remain limited, possibly due to structural underinvestment or data limitations.

The third research question – whether targeted SDG progress reduces future losses – yields more nuanced insights. Countries in the High SDG / Low Loss group, such as the Netherlands, Austria, and the Nordic states, tend to achieve strong outcomes in SDG 9 (infrastructure) and SDG 11 (urban resilience) while maintaining stable or declining loss levels. While cointegration between SDG trends and losses was not detected in this group, correlation patterns suggest that integrated urban and infrastructure planning may offer a buffering effect against future damage.

Concerning the fourth research question, several countries emerge as exemplars of balanced development and risk management. The Czech Republic, Slovenia, and the Netherlands consistently display high performance in SDGs related to climate resilience, while also incurring comparatively low economic losses. These cases highlight the potential benefits of long-term, cross-sectoral strategies that integrate risk mitigation into development pathways.

More broadly, the typology developed in this study underscores the structural asymmetry in how EU countries experience and manage climate risk. The absence of long-term cointegration between SDG indicators and economic losses confirms that development and resilience often evolve on parallel tracks. This disconnect implies that without explicit institutional integration, policy ambition may not translate into reduced vulnerability.

Notably, the analysis of reverse causality offers both diagnostic and normative insights. In countries with high exposure and lagging development progress, reactive adaptation appears to be the dominant approach. This dynamic raises concerns about the sustainability of resilience-building efforts that are only mobilised post-disaster. To address this, EU-level governance and funding frameworks should move beyond reactive compensation models and support anticipatory adaptation, for example, by tying cohesion funding to ex-ante vulnerability assessments and SDG-aligned investments.

Policy implications arising from this study are threefold. First, resilience strategies should be explicitly linked to development planning, especially in high-risk countries. Second, monitoring systems should incorporate temporal indicators, not just aggregate scores, to detect whether resilience progress is driven by planning or by necessity. Third, funding mechanisms should incentivise integrated, long-term adaptation, rather than short-term crisis response.

Nevertheless, this study faces several limitations. The analysis relies on aggregate national-level data, which may mask subnational disparities and sectoral vulnerabilities. While SDG scores offer functional comparability, they are influenced by variations in reporting and the availability of indicators. Additionally, the time horizon, although spanning two decades, may still be insufficient to capture slow-moving institutional reforms or intergenerational development effects. The analysis also does not include qualitative policy content, governance capacity, or financing mechanisms, all of which likely influence both resilience outcomes and exposure dynamics.

Future research should address these limitations by incorporating subnational data, exploring nonlinear and multivariate models, and enriching quantitative findings with case-based policy analysis. Understanding not only why, but also how, certain countries achieve better alignment between development and risk remains a crucial area for interdisciplinary scholarship.

In conclusion, this study contributes new evidence to a growing body of research that highlights the fragile alignment between sustainability and resilience. While SDG progress is essential, it is not a substitute for integrated risk governance. Conversely, building resilience without addressing development gaps risks entrenching vulnerability in new forms. Bridging this divide requires not only better metrics but also political and institutional innovation.

Conclusions

This study examined the intricate relationship between climate-related economic losses and progress toward the Sustainable Development Goals (SDGs) across European countries. By combining descriptive analytics, typological clustering, and time-series comparisons, we identified notable disparities in how countries absorb, mitigate, and respond to the economic consequences of climate change.

The findings suggest that high SDG performance alone does not guarantee lower economic losses from climate extremes. Structural factors such as geographic exposure, infrastructure concentration, and the legacy of economic development patterns continue to shape national vulnerability. Nevertheless, certain SDG domains, particularly those related to infrastructure, innovation, and urban resilience, appear to contribute to more stable or moderate loss profiles over time.

The typology developed in this study provides a practical lens for understanding divergent national pathways. Countries with both high SDG progress and low economic losses, although few, demonstrate the potential value of integrating sustainability planning with proactive risk management. Conversely, states with high losses and low SDG performance underscore the urgency of closing institutional and investment gaps.

Overall, the study contributes to the growing field of integrated resilience assessment by linking two key policy frameworks: disaster loss tracking and sustainable development monitoring. It highlights the need for coordinated methodologies that assess not only whether countries are progressing on development goals, but also how resilient that progress is in the face of escalating climate risks.

Future research should build on these insights by incorporating more granular, subnational data, and by exploring dynamic interactions between institutions, investments, and exposure. This would support the design of more context-specific strategies that can reduce both risk and inequality in the transition to a climate-resilient Europe.

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