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Jakub WINIAREK*
Tomasz DOROŻYŃSKI**
https://orcid.org/0000-0003-3625-0354

WHY DO WE NEED A GEOGRAPHIC INFORMATION SYSTEM AS A TOOL FOR CRISIS MANAGEMENT? A RESEARCH AGENDA

Abstract

Background: The effects of climate change and rapid urbanisation have created conditions for unprecedented economic turbulence, contributing to heightened volatility in global markets. Thus, we need an effective tool to manage asymmetric shocks. Geographic Information Systems (GIS), with their capacity to integrate diverse datasets, model risk scenarios, and support strategic planning, have emerged not only as instruments for crisis management but also as drivers of comprehensive structural economic change.

Research purpose: The article aims to provide a systematic review of the existing literature on GIS applications in crisis management, with a particular focus on their economic implications. We also intend to develop a research agenda to address the existing gaps in our understanding of the topic.

Methods: We used an in-depth literature review together with formulating research questions in the context of scientific and institutional sources as well as analysing empirical findings to investigate the role of GIS in crisis management.

Conclusions: GIS are shown to be more than merely technical instruments for hazard mapping; in a broader sense, they serve as economic tools for quantifying avoided losses and as catalysts that enhance regional investment attractiveness.

Keywords: Geographic Information Systems, management, crisis, resilience, investment, FDI.

JEL classification: F23, Q54, R58

* Student of Economics, Bachelor's Degree, Institute of Economics, Faculty of Economics and Sociology, University of Lodz, Corresponding Author; e-mail: jakub.winiarek@edu.uni.lodz.pl

** Dr. Hab., Professor of the University of Lodz, University of Lodz, Department of International Economics, Institute of Economics, Faculty of Economics and Sociology; e-mail: tomasz.dorozynski@uni.lodz.pl

1. Introduction

The frequency and severity of natural disasters are continuously increasing. The combined effects of climate change and rapid urbanisation have created conditions for unprecedented destabilisation of national and international economies, contributing to heightened volatility in global markets. The impact of these factors is evident in the deepening stagnation trends, particularly in Africa, as well as in the worldwide growth of debt markets and the shifting structure of investment capital flows.

According to the 2024 Emergency Events Database report, economic losses from natural disasters totalled $242 billion and affected 167.2 million people worldwide.[1] The most significant relative losses consistently occur in Africa and Asia, where disasters in low- and middle-income countries can exceed 5% of annual GDP, significantly destabilising fiscal policies. This, in turn, generates additional economic losses by reducing foreign direct investment (FDI) inflows to developing countries as investors attempt to mitigate risk exposure.[2]

These challenges, coupled with the increasing internationalisation of economies, underscore the urgent need for innovative tools that can build both economic and social resilience to crises, particularly in regions most exposed to such risks. Geographic Information Systems (GIS), with their capacity to integrate diverse datasets, model risk scenarios, and support strategic planning, have emerged not only as instruments for crisis management but also as drivers of comprehensive economic structural transformation.

By enabling detailed risk mapping, optimising resource allocation, and supporting early warning mechanisms, GIS can counter negative investment sentiment and foster resilient environments that are conducive to development. However, despite the significant technological advances in GIS, their application in mitigating economic and social losses remains limited, and their role and macroeconomic potential remain largely unexplored. While some studies have highlighted the economic benefits of disaster risk reduction[3]

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1 **EM-DAT**, *The International Disaster Database*, CRED, 2023, https://files.emdat.be/reports/2023_EMDAT_report.pdf; accessed 27.09.2025.

2 **UNCTAD**, *World Investment Report 2024: Investment facilitation and digital government*, United Nations, 2024, https://unctad.org/system/files/official-document/wir2024_en.pdf; accessed 27.09.2025.

3 **S. Hallegatte et al.**, *Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters*, World Bank, 2016, https://documents.worldbank.org/en/publication/documents-reports/documentdetail/512241480487839624/unbreakable-building-the-resilience-of-the-poor-in-the-face-of-natural-disasters; accessed 27.09.2025.

and others have employed GIS to estimate infrastructure vulnerabilities,[4] there is a notable paucity of research integrating GIS with macroeconomic indicators such as avoided losses, sovereign risk, or FDI dynamics.

This gap is particularly striking given the growing use of geospatial data in public policy and investment strategies, exemplified by the European Union INSPIRE Directive (2007/2/EC), which mandates the harmonisation of geospatial data for environmental and economic planning purposes.[5] The lack of comprehensive frameworks linking GIS with macroeconomic resilience limits its potential for evidence-based policy-making and for attracting sustainable investments, especially in regions facing institutional and structural weaknesses.

This article, the first in a planned series of publications, aims to address this oversight through a systematic review of the existing literature on GIS applications in crisis management, with a particular focus on their economic and investment implications. By synthesising findings from multiple disciplines, including disaster risk management and economic resilience frameworks such as those proposed by the United Nations Office for Disaster Risk Reduction and the World Bank, this study seeks to establish a solid theoretical foundation for analysing the macroeconomic contributions of GIS.[6] Furthermore, it identifies critical research gaps, particularly the absence of integrated approaches that connect GIS-based disaster mitigation with avoided economic losses, enhanced fiscal stability, and improved investment climates. Through this exploration, the article lays the groundwork for subsequent empirical and comparative research within the planned research cycle, providing insights that can support policymakers, financial institutions, and investors in leveraging GIS to develop resilient and sustainable economic systems.

2. GIS, crisis management, and investment

The evolution of GIS dates back to the 19th century, in primitive yet groundbreaking practices of hazard mapping. It was based on manual map creation and field observations, including historical records of river floods from

[4] **E.E. Koks et al.**, *A global multi-hazard risk analysis of road and railway infrastructure assets*, Nature Communications 2019/10, p. 2677, https://doi.org/10.1038/s41467-019-10442-3

[5] **European Union**, *Directive 2007/2/EC… (INSPIRE)*, Official Journal of the European Union 2007/L 108, pp. 1–14; accessed 25.04.2007.

[6] **UNDRR**, *Global Assessment Report on Disaster Risk Reduction 2020*, UNDRR, 2020, https://www.undrr.org/publication/undrr-annual-report-2020; accessed 27.09.2025.

France, England, and other locations. These attempts were the first to systematise risk assessment. However, it was not until the 1960s that a true breakthrough occurred, thanks to the work of the United States Geological Survey (USGS) in creating seismic risk maps. At that time, innovative GIS solutions were utilised, including the integration of spatial data with environmental variables, which created much more advanced and precise visual representations of potential hazards, which subsequently influenced early political decisions.[7]

Due to limited computational capabilities and data availability, early assessments primarily relied on qualitative criteria. With subsequent technological advancements, quantitative approaches became feasible and increasingly common. This was a groundbreaking step because decision-makers finally gained data that allowed them to prioritise resource allocation in proven high-risk areas. Over time, advancing satellite imaging, remote sensing, and computer modelling technologies enabled the evolution of GIS in the second half of the 20th century from a set of tools for static mapping to dynamically integrated data from multiple sectors, including urban planning, transportation, and energy infrastructure management. Thanks to these breakthroughs, integrated systems were developed that not only estimated the occurrence of risks but also facilitated planning for resilient infrastructure. This transformation was described in detail by Goodchild.[8] The first large-scale implementation of this sectoral synergy occurred after the Kobe earthquake in 1995, which primarily involved redesigning entire city layouts to enhance future seismic resilience. In a sense, the occurrence of these disasters was necessary for the complete metamorphosis of GIS into an epistemic-practical core of modern crisis management architecture, capable of responding to the escalating dynamics of catastrophic risks.

Applications of GIS that extend beyond conventional tools, thereby encompassing the entire disaster management cycle – from prevention to recovery – have been widely studied and documented in the literature, describing their implementation at both local and national levels. For example, early warning and monitoring systems have proven strategically important in reducing human and economic losses, which is reflected in their deployment in countries highly prone to natural disasters, as well as in those that are wealthy and institutionally strong enough to implement such systems at a nationwide level.

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7 **I. Burton**, **R.W. Kates**, **G.F. White**, *The Environment as Hazard*, Guilford Press, 1993, https://doi.org/10.1177/030913339501900310

8 **M.F. Goodchild**, *GIS and disasters: Planning for catastrophe*, Computers, Environment and Urban Systems 2006/30 (3), pp. 227–229, https://doi.org/10.1016/j.compenvurbsys.2005.10.004

Examples of such countries include Japan[9] and the Netherlands,[10] where the integration of real-time geospatial data has enabled rapid evacuations and resource deployment during events such as tsunamis or floods. A globally recognised system that exemplifies this advanced mechanism is the Japanese Earthquake Early Warning System, which uses GIS to map the propagation of seismic waves, significantly shortening response times and saving numerous lives during the 2011 Tōhoku earthquake.[11] Spatial planning and prevention, as another essential application, use GIS to model scenarios of optimal and safe land use as well as to enforce spatial planning regulations, which significantly minimises exposure to hazards. Studies, such as those by Cova and Church, demonstrate how GIS-based risk assessments have influenced urban development policies in flood-prone regions of the United States. The effects of these efforts, combined with other governmental programs, are clearly visible in mortality rate indicators in the USA.[12]

The role of GIS in coordinating emergency response operations was clearly demonstrated in the aftermath of Hurricane Katrina in 2005, where various geographic information systems supported rescue operations by mapping flooded areas and critical infrastructure in real-time.[13] It should be noted that post-disaster reconstruction and the principle of "build back better," promoted by frameworks such as the Sendai Framework for Disaster Risk Reduction,[14] primarily rely on GIS for setting priorities in reconstruction efforts and integrating resilience into infrastructure planning. This was observed in the case of recovery

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9 **S. Koshimura et al.**, *Advances of tsunami inundation forecasting and its future perspectives*, in: *OCEANS 2017 – Aberdeen*, IEEE, Piscataway, NJ 2017, pp. 1–4, https://doi.org/10.1109/OCEANSE.2017.8084753

10 **C.J. Van Westen**, *Remote Sensing and GIS for Natural Hazards Assessment and Disaster Risk Management*, *Treatise on Geomorphology*, Academic Press, San Diego 2013, vol. 3, pp. 259–298, https://doi.org/10.1016/B978-0-12-374739-6.00051-8

11 **Y. Fujinawa**, **Y. Noda**, *Japan's earthquake early warning system on 11 March 2011: Performance, shortcomings, and changes*, Earthquake Spectra 2013/29 (1), pp. 341–368, https://doi.org/10.1193/1.4000127

12 **I.M. Goklany**, *Integrated strategies to reduce vulnerability and advance adaptation, mitigation, and sustainable development*, Mitigation and Adaptation Strategies for Global Change 2007/12, pp. 755–786, https://doi.org/10.1007/s11027-007-9098-1

13 **S.L. Cutter et al.**, *The long road home: Race, class, and recovery from Hurricane Katrina*, Environment: Science and Policy for Sustainable Development 2006/48 (2), pp. 8–20, https://doi.org/10.3200/ENVT.48.2.8-20

14 **UNDRR**, *Sendai Framework for Disaster Risk Reduction 2015–2030*, United Nations, 2015, https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030; accessed: 27.09.2025.

following the economically devastating earthquake in Haiti in 2010, where GIS mapped the destroyed areas, supporting the equitable distribution of resources during the rebuilding process.[15]

Despite significant progress in the applications of GIS and the general public's enthusiasm for these technologies, which the authors themselves share, literature reveals several persistent limitations and challenges that hinder optimal utilisation in crisis management, especially from a macroeconomic perspective. Data availability and quality remain recurring issues, consistently posing significant barriers in low-income countries, where incomplete or outdated datasets reduce the accuracy of risk models based on GIS; as Van Westen notes, the lack of high-resolution spatial data in Sub-Saharan Africa has repeatedly limited the effectiveness of disaster preparedness strategies.[16] Technological disparities between countries, resulting from unequal access to advanced GIS tools and expert knowledge, further exacerbate the adverse variation in disaster management outcomes. For example, Japan employs advanced systems, whereas Southeast Asian regions struggle with fragmented implementations. These neglects between jurisdictions, as highlighted by Goodchild, complicate coordination in crisis responses.[17] This was particularly evident during the 2004 Indian Ocean tsunami.

The literature reveals noticeable gaps in the analysis of the economic dimension in GIS research, with few studies exploring how the implementation of GIS systems translates into tangible macroeconomic benefits, such as increased fiscal stability and enhanced investment attractiveness. Although works adequately quantify the economic benefits of disaster risk reduction, they rarely integrate GIS data into broader economic frameworks, leaving a gap in understanding how spatial analysis overall impacts the economy.[18] This gap, particularly evident in the context of global frameworks such as the EU INSPIRE Directive (2007/2/EC),[19] which focuses on harmonising geospatial data but does not explicitly consider economic applications, limits the potential of GIS as a catalyst for systemic economic resilience. This stems from a lack of widespread promotion of the tangible benefits derived from system integration, which may result in policymakers remaining indifferent towards them.

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15 **R. Bilham**, *Lessons from the Haiti earthquake*, Nature 2010/463 (7283), pp. 878–879, https://doi.org/10.1038/463878a

16 **C.J. Van Westen**, *Remote sensing…*

17 **M.F. Goodchild**, *Twenty years of progress: GIScience in 2010*, Journal of Spatial Information Science 2010/1, pp. 3–20, https://doi.org/10.5311/JOSIS.2010.1.2

18 **S. Hallegatte et al.**, *Unbreakable…*

19 **European Union**, *Directive 2007/2/EC…*

Internationalisation is undoubtedly one of the significant developments shaping the contemporary global economy. It occurs when, for instance, enterprises establish diverse cross-border relationships with their counterparts in other countries, typically starting with relatively simple forms, such as exports, and then progressing to more advanced ones. These more advanced forms include foreign direct investment (FDI), which is seen as a reflection of the activities pursued by multinational enterprises (MNEs).[20] In light of empirical studies, the assessment of FDI's effect on the host country's economy is somewhat ambiguous,[21] although most opinions about FDI's impact are positive.[22] They highlight, above all, the FDI effect on economic growth through capital flows, as well as technology and knowledge transfers. Multinational enterprises are seeking optimal locations in nearly all countries and regions worldwide that are both politically and economically stable.

A foreign investor is primarily interested in finding a specific area where they can bring the project to a successful conclusion. With this knowledge in mind, countries and their constituent parts attempt to attract foreign investors by utilising public resources for this purpose.[23] The authorities have realised that foreign investors are, above all, interested in a concrete location where they can carry out their projects. Even if they identify a suitable country in the first step, in the second, they must select a location within that country that ensures the best conditions for launching and developing economic activity. Under such circumstances, regions can compete for foreign investors and convince them that by locating their investment in their respective area, they will make the best choice. Only the most competitive regions, those best placed for success, can win this rivalry, and their competitiveness largely depends on the decisions and involvement of local and regional authorities.[24]

20 Por. **P. Trąpczyński**, *Determinants of Foreign Direct Investment Performance – A Critical Literature Review*, Oeconomia Copernicana 2013/2, pp. 117–132.

21 **M. Blomström**, **A. Kokko**, *Multinational Corporations and Spillovers*, Journal of Economic Surveys 1998/12 (3), pp. 247–277.

22 **T. Vissak**, **T. Roolaht**, *The Negative Impact of Foreign Direct Investment on the Estonian Economy*, Problems of Economic Transition 2005/48 (2), pp. 43–66.

23 **J. Świerkocki** (red.), *Foreign Direct Investment. The Case of Lodz Region*, Łódzkie Towarzystwo Naukowe, Łódź 2011.

24 **M. Jaworek**, **M. Kuczmarska**, *Kreowanie klimatu inwestycyjnego na rzecz przyciągania inwestorów zagranicznych przez jednostki samorządu terytorialnego województwa kujawsko-pomorskiego*, Finanse, Rynki Finansowe, Ubezpieczenia 2016/1 (79), pp. 665–677, http://dx.doi.org/10.18276/frfu.2016.79-53

To sum up, internationalisation is undoubtedly a significant development that is shaping the contemporary global economy. FDI flows originating from both developed and developing countries are growing dynamically as investors increasingly seek optimal locations for their capital. In 1980, the value of global FDI flows totalled $54 billion; ten years later, it had increased to $208 billion, and by 2022, it had reached $1.3 trillion. After a steep drop in 2020 and a strong rebound in 2021, global FDI declined by 12 per cent in 2022, to $1.3 trillion.[25]

The global poly-crisis, driven by factors such as the war in Ukraine, high food and energy prices, and debt pressures, contributed to the slowdown. Moreover, risks and uncertainties are influencing investments more than ever. What we are currently experiencing is a movement towards a less connected world, characterised by powerful nation-states, local solutions, and border controls rather than global institutions, treaties, and generally different freedoms. We observe the world experiencing a period of deglobalization, as evidenced by events such as Brexit, Trumpism, the war in Ukraine, and numerous other wars and regional conflicts worldwide, as well as supply chain issues and the global energy crisis. However, it would be incorrect to say that the world is definitely in a period of deglobalisation. Phenomena such as the COVID-19 pandemic, international crime and climate change paradoxically highlight the continuing importance of global cooperation and interdependence. It is difficult to argue that deglobalisation forces are inherently bad, as there are issues that are best addressed at the national level. The COVID-19 pandemic has highlighted the dangers of dependence on global supply chains for essential medical supplies or electronic components, and climate change requires a reduction in the huge carbon footprint associated with international trade.[26]

With this in mind, we should appreciate the value of EU membership all the more. The benefits of the single European market, EU cohesion policy and many other tools certainly outweigh the imperfections of bureaucracy, inefficient decision-making, inflexible procedures and even corruption. Aware of how much still lies ahead, we must make wise use of the achievements of the European Community in supporting internationalisation of businesses, and generally risk management at different levels.[27]

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[25] **UNCTAD**, *World Investment Report 2024: Investment facilitation and digital government*, United Nations, 2024, https://unctad.org/system/files/official-document/wir2024_en.pdf; accessed 27.09.2025.

[26] **M. Kornprobst**, **J**. **Wallace**, *What Is Deglobalization?*, Chatham House, 2022, https://www.chathamhouse.org/2021/10/what-deglobalization; accessed 27.09.2025.

[27] **S. Grima**, **et al.**, *Economic Development and Resilience by EU Member States*, Contemporary Studies in Economic and Financial Analysis Volume 115, 2024, Emerald Publishing, https://www.emerald.com/insight/publication/doi/10.1108/s1569-37592024115; accessed 27.09.2025.

When discussing crisis management, we must consider numerous challenges, which include, among others, wars and military conflicts, limited access to resources, administrative barriers, protectionism, and restrictions on international factor movements. However, one of the key challenges on a global scale is environmental threats, including the overexploitation of the natural environment and its impact on our quality of life. That is why we prioritise this aspect of international business activity in the context of crisis management.

3. The theoretical foundations of resilience and investment risk

The category of resilience, both in the economic and socio-institutional dimensions, is currently rising to the rank of one of the key analytical issues, determining the way in which the responses of state systems, local communities, national economies, or international institutions to crises are conceptualised, as well as the assessment of the long-term consequences of these responses. Leading global organisations generally highlight fundamental definitional elements, differentiating them only through shifts in interpretation. The United Nations Office for Disaster Risk Reduction[28] defines resilience as a system's capacity to absorb shocks, maintain essential functions, and adapt to evolving structural challenges. Conversely, the OECD (Organisation for Economic Co-operation and Development) regards resilience as a multidimensional construct, giving it a broader meaning and drawing attention to the interconnection between economic resilience, social equity, and institutional adaptability. It specifically stresses the importance of interactions between public policies and private investment flows in high-risk contexts. This approach proves especially relevant for economies where recurrent crises generate fiscal pressure and simultaneously erode investment attractiveness, resulting in limited inflows of FDI.

Infrastructure resilience, as a subset, focuses on the design and maintenance of physical systems in areas such as transport networks, energy grids, or urban settlements that are capable of withstanding shocks without losing functionality. The model for such investment design is Japan, which significantly increased investment in earthquake-resistant infrastructure following the 2011 Tōhoku earthquake.

Systemic resilience, on the other hand, extends beyond tangible assets to include institutional frameworks, social capital, and economic policies. When

[28] **UNDRR**, 2020, *Global Assessment Report…*

these are harmonised at local and national levels, rapid and equitable recovery after a disaster becomes possible. This style of governance for integrated flood management systems is exemplified by the Netherlands, which has extensive experience in spatial planning that involves local communities. By bridging economic, social, and infrastructural dimensions, these conceptual foundations create a solid basis for assessing how tools such as geographic information systems can enhance resilience, particularly in the context of mitigating investment risk and macroeconomic stability.

The theoretical foundations of investment risk assessment and the subsequent decision-making framework evolve in response to the increasing complexity of global economic systems. A closer examination of these developments reveals how natural and systemic disasters, as well as vulnerabilities, have been increasingly influencing capital allocation decisions for decades, particularly in regions prone to environmental and climatic shocks. This applies to investments made within the FDI model, particularly those that are more precise and capital-intensive, such as greenfield investments. It is also important to remember not only FDI but also domestic investments; regions often compete to demonstrate their maturity and investment security through such systems. Traditional approaches to capital risk, exemplified by the Capital Asset Pricing Model (CAPM) and Modern Portfolio Theory,[29] have primarily centred on market-related factors – volatility, liquidity, or interest rate fluctuations. Environmental threats, by contrast, were relegated mainly to the category of exogenous shocks, with little systematic incorporation into mainstream risk assessment frameworks. These models are fundamental in quantifying expected returns relative to risk and were effective a decade ago. However, they often overlook the cascade effects of natural disasters, which can destabilise entire economies through supply chain disruptions, inflation, debt market destabilisation, and reduced FDI inflows, as evidenced by a 22% decline in FDI in developed economies in 2024.[30]

New approaches, including those that consider climate risk and ESG criteria (environmental, social, and governance), have addressed these gaps by embedding systemic vulnerabilities into investment decisions. However, the quality of their implementation within corporate governance is often criticised. The climate risk

[29] **H. Markowitz**, *Portfolio Selection*, The Journal of Finance 1952/7(1), pp. 77–91, https://doi.org/10.2307/2975974

[30] **UNCTAD**, *World Investment Report 2025: International Investment in the Digital Economy*, United Nations, 2025, https://unctad.org/publication/world-investment-report-2025; accessed 27.09.2025.

frameworks formulated by the Financial Stability Board[31] highlight the need to quantify the financial impacts of climate-induced disasters – such as floods and hurricanes – on asset valuations and sovereign credit ratings, especially in low-income countries where losses can be disproportionately high. ESG frameworks, which are increasingly adopted by institutional investors, suggest a growing awareness of disaster resilience as a key determinant of long-term investment profitability. In this context, regions with robust risk mitigation strategies are highly valued. Disaster risk financing has been clearly illustrated through initiatives such as the Caribbean Catastrophe Risk Insurance Facility (CCRIF). Risk has been redefined through pooling and transfer mechanisms related to disasters, stabilising fiscal systems and strengthening investors. These evolving theories are not yet perfect, but their holistic approach to assessing investment risk is increasingly appreciated.

4. Economic effects of disasters and the existing research gap

The ability to assess the economic impacts of natural disasters in the context of detailed data, including losses, casualties, macroeconomic effects, and consequences beyond immediate human costs, depends on the richness of databases and the comprehensiveness and accuracy of institutional reports. The Emergency Events Database (EM-DAT), maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the University of Louvain in Belgium, serves as the basis for global monitoring, recording 393 events related to natural hazards in 2024, which caused economic losses of approximately $242 billion, 16,753 fatalities, and affected 167.2 million people.[32] These losses disproportionately burden low- and middle-income regions in Africa and Asia, where vulnerability to such events is exacerbated by climate change. Reports from the OECD highlight the political implications of these losses, indicating how the foundations of public debt stability are undermined and how inclusive growth is limited in member countries.[33]

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31 **Financial Stability Board**, *Roadmap for Addressing Financial Risks from Climate Change*, Financial Stability Board, 2025, https://www.fsb.org/2025/07/fsb-roadmap-for-addressing-financial-risks-from-climate-change-2025-update/; accessed 27.09.2025.

32 **EM-DAT**, *The International Disaster Database*, CRED, 2024, https://files.emdat.be/reports/2024_EMDAT_report.pdf; accessed 27.09.2025.

33 **OECD**, *Fiscal Risks, Fiscal Sustainability and Rethinking Fiscal Rules*, OECD, 2024, https://one.oecd.org/document/GOV/SBO(2024)10/en/pdf; accessed 27.09.2025.

Meanwhile, the World Bank's annual Global Economic Prospects integrates disaster data with broader macroeconomic forecasts. The latest estimates suggest that disaster-related losses in developing economies could reduce GDP growth by 1–2 percentage points annually, perpetuating cycles of poverty.[34] Insurers such as Munich Re and Swiss Re provide insights into insured and uninsured exposures; Munich Re's 2024 analysis indicates total economic losses around \$320 billion – primarily from weather-related disasters, accounting for over 90% – with insured losses around \$140 billion, suggesting a significant protection gap that burdens public finances and private sectors.[35] Swiss Re also confirms this trend, estimating economic losses at \$318 billion, of which 57% are from uninsured sectors.[36] These sources collectively outline global trends in economic losses, which, absent robust preventive measures such as integrated GIS applications, have shown a clear upward trajectory over the past decade, from approximately \$200 billion annually in the early 2010s to record levels observed in 2024. Asia and North America account for more than 60% of total damages, a consequence of high levels of urbanisation and the concentration of critical assets.[37] Yet, surprisingly few countries undertake systematic efforts to implement geospatial analyses as a means of mitigating such losses.

The measurement of avoided costs – defined as the total economic value of losses prevented through proactive interventions – constitutes a cornerstone of the economics of disaster risk. The integration of theoretical constructs with empirical validation is particularly indispensable in an era when fiscal resources are increasingly stretched by recurrent shocks, to capture the benefits ranging from prevention through to post-disaster recovery. Theoretical models, especially those grounded in cost–benefit analysis as developed by the World Bank, assume that investments in risk reduction generate returns several times greater than the initial

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34 **R. Middelanis et al.**, *Global Socio-economic Resilience to Natural Disasters*, Policy Research Working Paper 11129, World Bank, 2025, https://documents1.worldbank.org/curated/en/099542505212567521/pdf/IDU-c00f466d-e3e5-4c61-93f2-1e768a22b785.pdf; accessed 27.09.2025.

35 **Münchener Rückversicherungs-Gesellschaft** (Munich Re), *Natural disasters in 2024: Annual Review*, Munich 2025, https://www.munichre.com/content/dam/munichre/mrwebsitespressreleases/MunichRe-NatCAT-Stats2024-Full-Year-Factsheet.pdf/_jcr_content/renditions/original./MunichRe-NatCAT-Stats2024-Full-Year-Factsheet.pdf; accessed 27.09.2025.

36 **Schweizerische Rückversicherungs-Gesellschaft** (Swiss Re), *Sigma 1/2025: Natural Catastrophes and Climate Change*, Zurich 2025, https://www.swissre.com/institute/research/sigma-research/sigma-2025-01-natural-catastrophes-trend.html; accessed 27.09.2025.

37 **Münchener Rückversicherungs-Gesellschaft** (Munich Re), *Natural*...

outlays.[38] These gains arise not only from limiting direct damages (e.g. destruction of assets and infrastructure) but also from reducing indirect repercussions (e.g. supply chain disruptions and productivity losses). Estimates frequently suggest benefit–cost ratios exceeding 4:1 for measures such as early warning systems and disaster-resilient infrastructure. Econometric studies seek to identify the effects of prevention by comparing treatment and control groups. The analysis draws on EM-DAT and national accounts to construct counterfactual scenarios of disaster impacts in the absence of such expenditures. Previous efforts to quantify the effectiveness of prevention have been advanced in the *Unbreakable* report,[39] which integrates agent-based models to evaluate the socio-economic benefits of urban upgrading in low-income settings. The findings reveal that avoided losses from resilient housing construction may amount to $10–20 billion annually in megacities such as Dhaka and Manila. Such valuations remain highly contingent upon assumptions regarding behavioural responses and long-term adaptation, which continue to generate substantial debate within the literature.

Despite the proliferation of disaster impact data and the increasing maturity of avoided cost models, a significant research gap persists in integrating GIS with avoided cost analysis. This gap constrains both the precision and scalability of economic assessments in ways that could otherwise shed new light on fiscal stability. While EM-DAT and insurer reports provide robust aggregate loss figures, they rarely leverage the granularity of GIS data to disaggregate avoided costs at the subnational level. As a result, aggregate indicators often obscure heterogeneous vulnerabilities within countries, such as urban–rural divides exacerbated by uneven infrastructure resilience, thereby undermining the formulation of targeted policy prescriptions.[40] This issue critically extends to investment decision-making, where the absence of GIS-based avoided cost metrics hampers evaluations of how disaster mitigation influences FDI inflows, infrastructure financing, or urbanisation trajectories. Few studies connect this directly to geospatial risk modelling, leaving investors without adequate tools to estimate the economic benefits of GIS-enhanced planning in emerging markets. Compounding these challenges is the weak comparability across countries, driven by divergent data

[38] **World Bank**, *Building Safer Cities: The Future of Disaster Risk*, in: **A. Kreimer**, **M. Arnold**, **A. Carlin** (eds.), World Bank, 2003, https://documents1.worldbank.org/curated/en/584631468779951316/pdf/272110PAPER0Building0safer0cities.pdf; accessed 27.09.2025.

[39] **S. Hallegatte et al.**, *Unbreakable…*

[40] **UNDRR**, *Global Assessment Report on Disaster Risk Reduction 2019*, UNDRR, 2019, https://www.undrr.org/publication/global-assessment-report-disaster-risk-reduction-2019; accessed 27.09.2025.

standards, methodological variance in loss estimation, and institutional silos that obstruct harmonised benchmarks. Addressing this multidimensional gap – through interdisciplinary frameworks that integrate GIS with macroeconomic modelling – offers substantial potential to bridge the divide between theory and practice.

5. Research agenda

This research agenda, derived from the identified gap in the literature concerning the integration of GIS with macroeconomic and investment analyses, formulates a series of research questions that aim not only to deepen theoretical foundations but also to provide empirical underpinnings for the design of disaster risk reduction policies. Specifically, the first research question asks:

(RQ1) *How does GIS implementation help reduce the socio-economic losses resulting from natural disasters, taking into account heterogeneous institutional and technological contexts across regions where such losses may exceed 5% of GDP in developing economies?*

The second, investment-oriented question is:

(RQ2) *To what extent does GIS, through enhancing spatial risk modelling, influence the investment attractiveness of disaster-prone regions, as measured by FDI inflows and sovereign risk assessments?*

This issue is particularly salient in light of UNCTAD reports highlighting a 15–20% investment premium for highly resilient jurisdictions.[41] The third comparative question inquires: Which models of GIS implementation – ranging from centralised national systems to decentralised local applications – prove most cost-effective in reducing losses? This is examined through benefit–cost ratios in contexts such as the Dutch flood management systems or Japan's early warning networks, where World Bank analyses suggest efficiency levels of up to 4:1.[42]

[41] **UNCTAD**, *World Investment Report 2025: International…*

[42] **A. Tall et al.**, *Enabling Private Investment in Climate Adaptation and Resilience: Current Status, Barriers to Investment and Blueprint for Action*, World Bank, 2021, https://doi.org/10.1596/35203

Building on the literature review and theoretical frameworks presented in earlier sections, this agenda formulates two hypotheses. Both positive correlations between GIS maturity and key indicators of economic and investment resilience will be tested empirically in subsequent publications of the research cycle, using panel data drawn from EM-DAT, the World Bank, and composite indicators such as the GIS Maturity Index (GISMI).

H1: Higher GIS maturity, as measured by GISMI – which encompasses technological, institutional, and integrative dimensions – correlates negatively with the scale of socio-economic losses from natural disasters.

This implies that regions with advanced GIS systems record, on average, 20–30% lower avoided losses than areas of low maturity, such as Sub-Saharan Africa.

H2: There is a positive relationship between GISMI and investment attractiveness, as evidenced by higher per capita FDI inflows and lower sovereign bond risk premia.

Econometric models suggest that increases in the index may generate additional capital inflows, particularly in urbanising contexts such as Asian megacities.

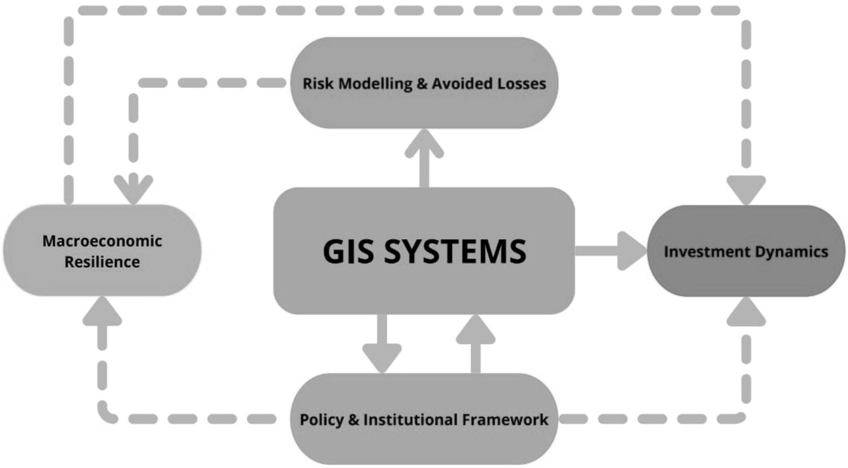
The conceptual framework proposed in this agenda is visualised as a sequential *causal chain*:

GIS → Avoided losses → Macroeconomic resilience → Investment dynamics

Integrating these elements produces a holistic model that not only explains the transmission mechanisms of GIS effects but also provides the basis for empirical testing in subsequent stages of the research cycle. Initially, GIS, as a tool for integrating geospatial data, enables precise hazard mapping and risk modelling. This directly generates avoided losses by minimising both direct damages (e.g., to infrastructure) and indirect repercussions (e.g., productivity losses). For instance, Hallegatte estimates that preventive scenarios can result in savings in the order of billions of dollars.[43] When aggregated, these avoided losses strengthen macroeconomic resilience – defined as an economy's ability to absorb shocks without significant GDP contraction or surges in public debt. Such resilience can establish fiscal buffers and stabilise indicators such as the Gini coefficient and HDI in vulnerable regions.

43 **S. Hallegatte et al.**, *Unbreakable…*

FIGURE 1: *Integrated GIS Framework for Economic Resilience*



Source: own elaboration.

6. Discussion and implications

Integrating GIS with development economics – moving beyond conventional hazard mapping towards a symbiotic fusion of spatial data with inclusive growth models – gains particular relevance in the context of global disparities. As highlighted by Esri, GIS not only identifies infrastructure deficits in developing regions but also forecasts the cascading effects of urbanisation.[44] For instance, disaster-resilient microgrids can generate hidden economic benefits by preventing supply disruptions, potentially raising GDP by 2–3% in Southeast Asian megacities.

This synergy, supported by the United Nations' Global Statistical Geospatial Framework, enables not only the harmonisation of statistical and geospatial data but also, increasingly, integration with artificial intelligence for adaptive scenario simulations.[45] In doing so, GIS reveals latent inequalities in access to resources. One striking example comes from African river deltas, where spatial analysis

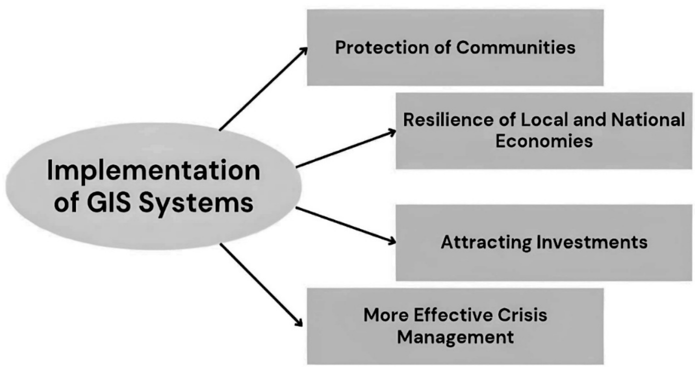
[44] **K. Cooke** (Esri), *The Role of GIS in Planning in 2025*, Esri Industries Blog 2025, https://www.esri.com/en-us/industries/blog/articles/role-of-gis-in-planning-in-2025; accessed 27.09.2025.

[45] **United Nations (UN-GGIM)**, *The Global Statistical Geospatial Framework*, 2nd ed., United Nations, 2025, https://ggim.un.org/meetings/GGIM-committee/15th-Session/documents/GSGF_v2_GGIM.pdf; accessed 27.09.2025.

suggests that investments in resilient agriculture could reverse climate-induced migration trends by 15–20%, thereby linking development economics with social dynamics in ways that traditional macroeconomic models often fail to capture.

The potential of GIS in public policy and investment strategies is particularly evident in the era of ESG and green bonds. Its strength lies in the ability to translate abstract regulatory frameworks into concrete, spatially grounded recommendations. As illustrated, federal agencies that integrate GIS with non-spatial datasets not only bridge information silos but also employ it for what has been termed "geofinance": the mapping of climate-resilient investment corridors.[46] Within the framework of the EU INSPIRE Directive, such approaches could enhance FDI attractiveness in Eastern Europe by 10–15% by visualising "safe zones" for critical infrastructure.

FIGURE 2: *Outcomes of GIS Implementation*



S o u r c e: own elaboration.

Further integration with Internet of Things (IoT) data enables real-time assessment of disaster impacts on supply chains, which could, in turn, revolutionise parametric insurance by triggering automatic payouts based on satellite maps, thereby stabilising public finances in low-income countries.

Guidance for future empirical research points towards the adoption of hybrid methods, such as panel analysis augmented with machine learning. In this context, researchers might explore the impact of GIS on the "butterfly effect" in global supply chains, testing whether spatial models can anticipate disruptions

46 **K. Chamberlain** (ICF), *How GIS integrations accelerate mission impact*, ICF, https://www.icf.com/insights/analytics/integration-gis-government; accessed 27.09.2025.

caused by localised floods. Using EM-DAT and World Bank datasets to construct counterfactual scenarios could reveal that advanced GIS systems reduce global losses by up to 25% by providing early, sector-specific alerts.

7. Conclusions

Geographic Information Systems have emerged not merely as technical instruments for hazard mapping, but in a broader sense, as economic tools for quantifying avoided losses and as catalysts for investment that enhance regional attractiveness.

In the era of climate change, as noted by UNDRR, investments in GIS-based resilience not only safeguard lives and assets but also build "geocapital" by integrating with ESG frameworks.[47] This approach enables regions such as the Caribbean to attract 20–30% more green financing through spatial resilience certificates. The multidimensional character of GIS, linking the precision of satellite data with macroeconomic modelling, underscores its role as a bridge across disciplines ranging from urban planning to risk finance. Consequently, non-traditional applications may revolutionise capital allocation decisions in megacities. GIS systems in this context create opportunities for investors and decision-makers to assess spatial determinants of FDI, such as infrastructure quality, labour resource allocation, or regulatory conditions. Integrating data with indicators provides significant possibilities for supporting decisions regarding the placement of capital outside national borders and increasing the resilience of these strategies not only geographically but also systemically.

The identified research gap – namely, the lack of holistic integration of GIS with avoided loss assessments and FDI dynamics – opens new avenues for interdisciplinary research. Economists, geoinformatics specialists, and policymakers could together explore underappreciated interactions, such as the influence of GIS on "spatial investor sentiment", analysed through big data from social media. Within the context of the Sendai Framework, such investigations could uncover hidden institutional barriers in developing countries, encouraging hybrid studies that combine econometric methods with spatial ethics. The subsequent stages of this research cycle – quantitative empirical analyses, complemented by qualitative case studies from Africa and Asia – aim to validate hypotheses H1 and H2. By incorporating unconventional extensions, these studies aim to ultimately strengthen public policy and stabilise development trajectories in the face of escalating risks.

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[47] **UNDRR**, *Global Assessment Report 2025*, UNDRR, 2025, https://www.undrr.org/gar/gar2025; accessed 27.09.2025.

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Jakub WINIAREK, Tomasz DOROŻYŃSKI

DLACZEGO POTRZEBUJEMY SYSTEMU INFORMACJI GEOGRAFICZNEJ JAKO NARZĘDZIA ZARZĄDZANIA KRYZYSOWEGO? AGENDA BADAWCZA

Abstrakt

Przedmiot badań: Skutki zmian klimatu oraz szybka urbanizacja tworzą warunki bezprecedensowej turbulencji gospodarczej i zwiększonej zmienności rynków. Potrzebne są narzędzia do zarządzania asymetrycznymi szokami. Systemy Informacji Geograficznej (GIS) – dzięki integracji zróżnicowanych danych, modelowaniu ryzyka i wsparciu planowania – wyłaniają się nie tylko jako instrumenty zarządzania kryzysowego, lecz także jako dźwignia szerszych zmian strukturalnych.
Cel badawczy: Przeprowadzamy systematyczny przegląd literatury na temat zastosowań GIS w zarządzaniu kryzysowym ze szczególnym uwzględnieniem implikacji ekonomicznych oraz formułujemy agendę badawczą niwelującą luki w dotychchczasowych badaniach.
Metoda badawcza: Dogłębny przegląd literatury i źródeł instytucjonalnych połączony z formułowaniem pytań badawczych oraz analizą ustaleń empirycznych dotyczących roli GIS w zarządzaniu kryzysowym.

Wyniki: GIS to więcej niż techniczny warsztat mapowania zagrożeń; w szerszym ujęciu stanowi narzędzie ekonomiczne do kwantyfikacji strat unikniętych oraz katalizator podnoszący atrakcyjność inwestycyjną regionów.

Słowa kluczowe: Systemy Informacji Geograficznej (GIS), zarządzanie, kryzys, odporność, inwestycje, ZIB.