

Mapping Health Risks: The Role of Geospatial Data in Protecting Communities and Driving Decisions



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The ability to anticipate and manage risks has always been central to the health of communities and the systems that serve them. Today, as challenges grow in scale and complexity, it's encouraging to see new tools emerge to meet the demands of these evolving threats.

Setting the Stage for Geospatial Health Analytics

Advanced data science, geospatial intelligence, and new sources of data – such as satellite imagery, sensor networks, and real-time social and environmental data – are transforming how we approach risk management. These tools and datasets offer a transformative opportunity to shift healthcare from its traditionally reactive stance of responding to crises or illness after they occur, to a proactive model that anticipates risks enabling timely interventions that can achieve better outcomes at lower costs.

GeoAI, or geospatial artificial intelligence, integrates these tools into a cohesive framework for risk management. By combining spatial context, predictive analytics, and broad and diverse datasets, GeoAI enables decision-makers to understand, anticipate, and address risks with greater precision and timeliness.

For example, GeoAI can overlay environmental factors with social determinants of health (SDOH) to identify neighborhoods most vulnerable to extreme heat, guiding targeted interventions like cooling centers or urban tree planting. It can also be used to track the spread of infectious diseases, integrating climate and mobility data to forecast hotspots and optimize resource allocation. With a more comprehensive picture of risk, organizations will be able to offer proactive solutions to protect both communities and the populations they serve.

A Convergence of Forces

In particular, health risk analytics is undergoing a paradigm shift thanks to three converging trends:

1. The growing accessibility of geospatial intelligence, empowering organizations to map and visualize risks with unprecedented clarity.
2. The increasing availability of social determinants of health (SDOH) data, providing critical insights into the interplay between socioeconomic factors and health outcomes.
3. Advances in machine learning algorithms enabling the discovery of patterns and risks in ways that were unimaginable just a decade ago.

These developments are reshaping how we assess and manage risks, especially in a world where challenges are mounting. An aging global population is creating new pressures on healthcare systems and the workforce. Simultaneously, increases in human mobility, land use change spurred on by continued urbanization, along with shifting weather and environmental factors are amplifying exposure

to harmful viruses, bacteria, as well as disease-carrying insects and mosquitos (Figure 1). The altered dynamics of infectious disease spread require new approaches to health risk management.

At the heart of this evolution is a recognition that effective risk management must both identify threats and go one step further to deliver actionable insights to the people who need them most. The convergence of geospatial intelligence, SDOH data, and advanced analytics offers a powerful framework for achieving this, ensuring that decision-makers can anticipate, plan for, and respond to risks with precision. From public health to emergency response, insurance, and supply chain resilience, GeoAI solutions can become indispensable tools for decision-makers across industries.



Figure 1: Dengue carrying Aedes aegypti mosquitos have been found in the US.

The Power of Geospatial Intelligence

Geospatial intelligence can provide the critical context needed to understand where and how health threats emerge. Integrating location-based information with environmental, demographic, and health data on a single map advances risk modeling and visualization producing actionable insights that decision makers need to address complex challenges effectively.

One example of the power of geospatial tools lies in monitoring the spread of mosquito-borne diseases such as dengue fever and malaria. By overlaying disease incidence with environmental and demographic data, health officials can pinpoint hotspots, predict regions of disease spread, deploy targeted interventions, and optimize resource allocation.

Similarly, in the face of natural disasters like wildfires, geospatial analytics can model the effects of poor air quality on respiratory health. This enables emergency responders to issue timely alerts and direct assistance to the most affected communities, mitigating harm and saving lives. In urban settings, geospatial data is critical for identifying heat islands—neighborhoods with higher temperatures due to dense infrastructure and limited green spaces (Figure 2). By highlighting these vulnerable areas, city planners and public health agencies can implement cooling strategies, such as creating green spaces, establishing hydration stations and cooling centers, and planting trees for natural shade to reduce heat-related illnesses. (For more information, please visit [Heat-Health Risk Index](#).)

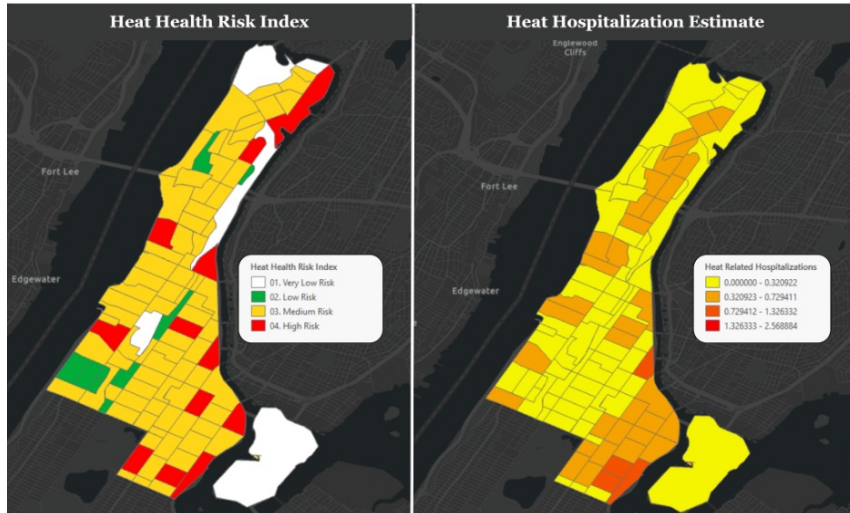


Figure 2: Heat Health Risk Index & Hospitalization Estimate for a portion of N Manhattan, Summer 2024.

Geospatial intelligence distills complex datasets into insights that are easy to understand and act upon. This ability to visualize risks—whether as a global map of disease hotspots or a neighborhood-level assessment of climate vulnerability—empowers decision-makers to prioritize their responses effectively. Public health agencies can use geospatial data to equitably allocate resources during outbreaks or disasters. Health systems can anticipate surges in demand, plan hospital capacity, and identify underserved areas in need of mobile clinics. Geospatial insights can allow insurers to assess risks more accurately, enabling them to design innovative products for populations facing unique health or environmental challenges. Supply chain managers integrate geospatial intelligence to predict disruptions caused by crises and reroute critical medical supplies and equipment.

At its core, geospatial intelligence bridges the gap between data and decision-making. It ensures that the right people in the right places receive the resources and support they need to manage risks effectively. By transforming reactive responses into proactive strategies, geospatial intelligence not only enhances individual interventions but also contributes to broader systems of resilience and preparedness.

The Role of SDOH Data

Social determinants of health (SDOH) add a crucial layer of insight to health risk analytics. These factors—such as income, education, housing stability, food security, transportation, and population dynamics—shape health outcomes as much as, if not more than, clinical care. When combined with geospatial intelligence, SDOH data creates a multidimensional view of risks, enabling public health decision-makers to tackle both immediate health crises and the systemic inequities that contribute to them.

Consider the example of asthma in low-income urban neighborhoods. By integrating data on air quality, traffic density, and housing conditions with income and demographic information, geospatial tools can map asthma hotspots and identify populations most at risk. With this information, health agencies, policymakers, and urban planners can work to reduce disparities in respiratory health outcomes through, for example, improved access to healthcare services.

Another example is the concept of healthcare deserts – areas with insufficient facilities and services to meet the healthcare needs of the population. Geospatial data, combined with SDOH insights such as

transportation systems and income levels, can pinpoint these underserved regions. For instance, in rural areas where populations are spread thin and healthcare resources are scarce, the integration of SDOH and geospatial data can guide the placement of mobile clinics or for telehealth services to bridge the gap. Similarly, in urban settings, mapping transportation networks alongside healthcare facility locations can highlight where expanding public transit or creating community health centers would have the greatest impact.

The integration of SDOH with geospatial intelligence allows decision-makers to connect the dots between environmental, social, and health-related factors. For example, during a heatwave, geospatial data can map areas experiencing extreme temperatures, while SDOH data can identify neighborhoods with vulnerable populations, such as elderly residents or those with limited access to cooling resources. This combined intelligence empowers public health officials to prioritize interventions, such as establishing cooling centers, or improving the HVAC systems to more efficiently cool buildings within hotspots.

Beyond addressing immediate crises, the integration of SDOH and geospatial data also helps tackle systemic health inequities. It reveals the underlying patterns of disparity, such as how historical redlining contributes to urban heat islands or how food insecurity correlates with higher rates of chronic diseases in certain communities. By uncovering these connections, decision-makers and urban planners can design more holistic, long-term strategies to promote community well-being and resilience.

Ultimately, the geospatial analysis of SDOH has the potential to be transformative in public health. It can help address the broader context in which health outcomes occur, enabling more effective and equitable solutions for communities locally and globally.

Machine Learning and Analytics—Unlocking Patterns and Predictions

Machine learning (ML) has revolutionized health risk analytics by enabling the analysis of vast and complex datasets to uncover patterns, forecast risks, and generate actionable insights. ML algorithms excel at finding relationships in data that may be missed by humans due to the quantity of the data. When integrated with geospatial and SDOH data, these capabilities offer transformative possibilities for improving health outcomes and operational efficiency.

One example is in the prediction of infectious disease spread. By analyzing geospatial data alongside environmental and demographic variables, ML models can forecast disease hotspots and transmission patterns. For example, during the COVID-19 pandemic, ML algorithms were used to predict surges in cases, enabling public health officials to allocate resources like testing sites, personal protective equipment, and vaccines more effectively. Similarly, ML-driven models have been employed to monitor mosquito-borne illnesses such as malaria or dengue fever, providing early warnings for areas at risk of zoonotic disease spillover events (Figure 3) as well as identifying the underlying factors contributing to expansion of risk regions.

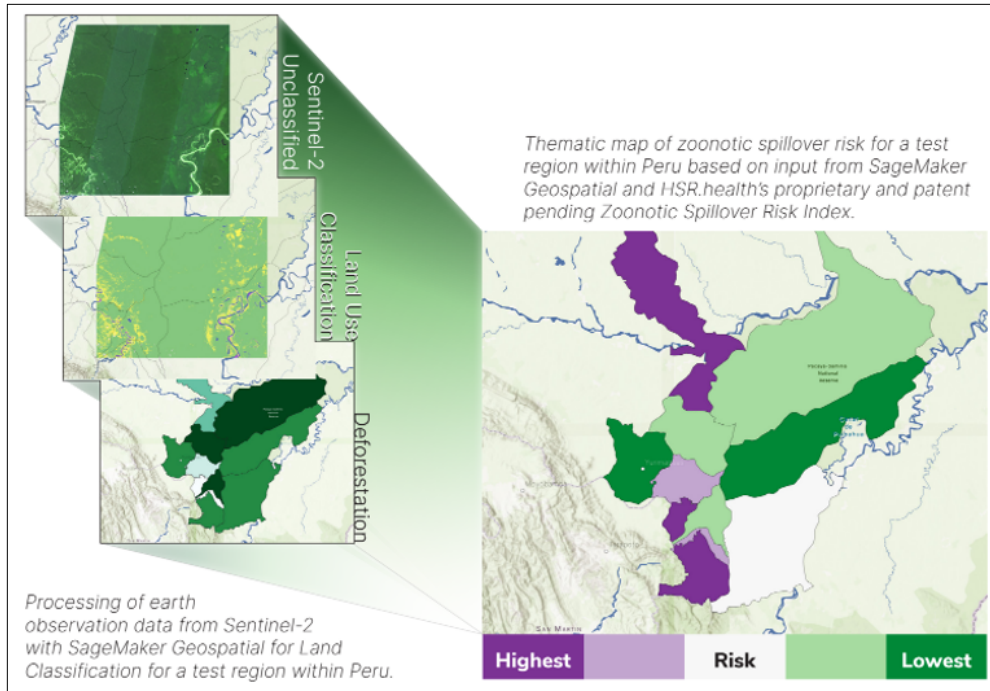


Figure 3: Peru Zoonotic Spillover Risk Index

Another critical application is modeling hospital resource needs during disasters. ML tools can analyze historical data on patient admissions, weather conditions, and disaster impacts to predict hospital surges. This capability helps healthcare systems prepare for emergencies by optimizing staffing, ensuring adequate supplies, and streamlining workflows. For instance, ML models can predict an increase in emergency room visits due to extreme heat or respiratory illnesses caused by wildfire smoke, allowing hospitals to proactively adjust their operations.

However, the use of machine learning in health risk analytics comes with challenges that must be addressed. One of the most pressing issues is the need for high-quality training data. Machine learning models are only as good as the data they are trained on, and incomplete, biased, or inaccurate data can lead to flawed predictions. Ensuring access to comprehensive, reliable datasets requires collaboration across sectors and significant investment in data collection and curation.

Another challenge lies in overcoming data silos and lack of interoperability. Health, geospatial, and social datasets are often stored in disparate systems with incompatible formats, making integration difficult. Without seamless interoperability, the power of machine learning to draw insights from diverse data sources is significantly diminished. Addressing this requires orchestration and a commitment to secure data curation from sources not traditionally included in health analysis.

In addition to data-related challenges, the high computational costs of running advanced ML models present a barrier, particularly as the scope and scale of analytics increase. Complex algorithms that process large datasets require significant cloud or on-premises compute resources which can strain operating budgets, especially for those with limited resources. Balancing the need for advanced analytics with cost considerations is a growing concern. Leveraging cloud-based solutions, such as those offered by AWS, and optimizing models for efficiency can help mitigate these costs while maintaining analytic rigor. This remains an area of potential growth.

Machine learning promises a new era of health risk analytics, offering unprecedented insights and predictive capabilities. However, its success depends on addressing the challenges of data quality, interoperability, and computational costs. By investing in robust data infrastructure and curating data across sectors, organizations can harness the full potential of ML to build a healthier, more resilient future.

Environmental Risks and Health Analytics

The influence of our environment extends deeply into our health at a personal and community level, as rising temperatures, extreme weather events, and other changes create new challenges and amplify existing risks. Health outcomes are profoundly impacted by these shifts, making climate-integrated health analytics an essential tool for proactive risk management.

Rising global temperatures can lead to a sharp increase in heat-related illnesses. Heat stress, heat exhaustion, and heatstroke are becoming more common, particularly in urban areas where the phenomenon of heat islands exacerbates high temperatures, as well as for outdoor laborers who may have little respite from the heat.

Urban heat islands, caused by dense infrastructure and a lack of greenery, disproportionately affect low-income neighborhoods, where access to cooling resources is often limited. By analyzing geospatial data, climate trends, and SDOH insights, public health officials can identify at-risk areas and implement targeted interventions such as cooling centers, urban tree planting initiatives, and public health campaigns to mitigate these risks.

Air quality is also an important factor. Wildfires, industrial emissions, and the proliferation of allergens due to longer growing seasons are impacting air quality worldwide. Poor air quality is closely linked to asthma, COPD, and other respiratory illnesses. GeoAI methods can identify regions with deteriorating air quality and overlay this information with demographic and health data to pinpoint vulnerable populations. This insight allows for timely public health responses, such as issuing air quality alerts and deploying mobile health clinics.

Waterborne diseases are another significant health risk. Flooding events, often driven by rising sea levels and changes in rainfall patterns, can overwhelm sanitation systems, contaminating drinking water supplies with harmful bacteria and viruses. Conversely, droughts can limit access to clean water, exacerbating water scarcity and hygiene challenges. Combining climate data with geospatial intelligence provides a clearer picture of regions prone to such risks, enabling health agencies and policymakers to prioritize interventions such as improving water infrastructure, delivering hygiene education, and preemptively stockpiling water purification supplies.

Vector-borne diseases such as malaria, dengue fever, and Lyme disease are also on the rise as changing temperatures and precipitation patterns expand the habitats of disease-carrying organisms including mosquitoes and ticks. Environmental data integrated with geospatial and SDOH insights can help predict where these vectors are likely to thrive, allowing public health officials to deploy targeted vector control measures, vaccination programs, and public education campaigns.

GeoAI analytics brings these diverse threats into a unified framework, providing decision-makers with a comprehensive view of health risks. By combining climate data with geospatial and SDOH insights, health risk analytics can go beyond addressing immediate health crises to inform long-term strategies for

resilience and adaptation. For example, analyzing historical weather patterns, disease prevalence rates, and health outcomes to model trends into the future can guide investments in healthcare infrastructure, urban planning, and public policy to better prepare for future challenges.

The environment we live in profoundly shapes the risks we face, from the air we breathe to the diseases we encounter. Integrating weather data into health risk analytics is not just a technological advancement – it is an ethical imperative to protect human lives and build a healthier, more resilient future. Leveraging this approach is essential for mitigating health risks today and into the future to safeguard communities around the world.

The Struggle to Make Data Useful

Despite the incredible potential of geospatial and health risk analytics, one significant hurdle remains: Making data useful. While advancements in technology have given us unprecedented access to vast datasets, the reality of collecting, integrating, and cleaning data from disparate sources is fraught with challenges. For data to drive actionable insights, it must be transformed into a format that is not only accurate but also accessible and interpretable by decision-makers across various sectors.

Data Curation Challenges

Health and geospatial data are often scattered across multiple systems, each with its own standards, formats, and levels of completeness. Public health agencies, private sector organizations, and research institutions all collect valuable information, but these datasets frequently exist in silos. Integrating these sources requires navigating issues such as incompatible formats, missing or incomplete data, regulatory and data sharing requirements, and variability in data quality. For example, combining hospital admission data with environmental data might involve reconciling discrepancies in geographic boundaries, timeframes, and collection methods.

These challenges are compounded by the sheer volume of data generated daily, creating a bottleneck that slows down the transformation of raw information into actionable insights. Open-source platforms, cloud-based tools, APIs, and user-friendly interfaces are democratizing access by expanding access to critical data.

The process of cleaning and standardizing data is equally demanding. Datasets often include errors, inconsistencies, and redundancies that must be addressed before analysis can begin. For example, geospatial datasets might contain outdated maps or inaccurate coordinates, while health data may suffer from incomplete patient records or coding errors. Addressing these issues requires significant time, resources, and domain-specific expertise, often straining the capacities of organizations attempting to leverage these tools.

Bridging the Gap

Transforming raw data into actionable decision support requires tools that simplify access and interpretation. This is where solutions like Anna, our generative AI orchestrator, come into play. Anna's ability to curate, synthesize, and present data through a conversational interface transforms complex analytics into intuitive insights that are easy for decision-makers at all levels to understand. By reducing the technical barriers to accessing data, Anna empowers public health officials, emergency responders, and risk managers to make informed decisions quickly and confidently.

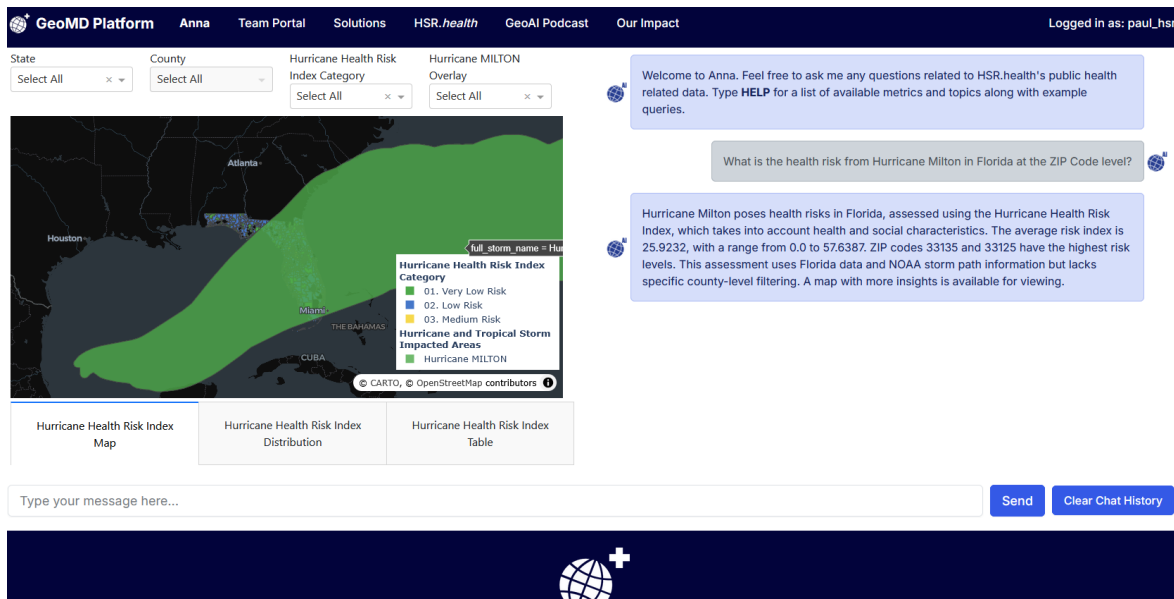


Figure 4: Anna Responding to a Hurricane Risk Question

For example, during a natural disaster, Anna can integrate real-time geospatial and SDOH data to identify areas facing the greatest health risk (Figure 4), as well as recommend resource allocation strategies such as locations for food and water distribution. Similarly, Anna can analyze historical climate trends alongside current hospital data to predict healthcare needs during extreme weather events. These capabilities not only enhance the usability of data but also democratize access, allowing a wider range of stakeholders to benefit from advanced analytics.

Collaboration Across Sectors

Making data truly impactful requires collaboration between public health agencies, private sector risk managers, and technology providers. Public health entities often have access to critical data but may lack the technological infrastructure to analyze it effectively. Meanwhile, private sector organizations such as insurers or supply chain managers bring advanced analytical tools and methodologies to the table but may lack access to comprehensive health datasets. Technology providers bridge this gap by offering platforms and expertise to integrate, analyze, and visualize data from multiple sources.

For example, during wildfire outbreaks in the western United States, partnerships between public health agencies, private organizations, and geospatial technology providers enabled the development of dashboards that combined satellite imagery, air quality data, and health records. These tools allowed decision-makers to monitor health impacts, allocate medical resources, and communicate risks to affected communities in real time. These collaborations highlight the power of shared resources and expertise in addressing complex challenges. Moving forward, fostering such partnerships will be essential to overcoming data silos and ensuring that analytics translate into meaningful action.

Paving the Way for Smarter Analytics

The struggles in the journey from raw data to actionable insights is justified by its rewards. By addressing data curation challenges, leveraging tools like Anna, and fostering cross-sector collaboration, we can

unlock the full potential of GeoAI-based health risk analytics. Together, these efforts can ensure that data not only informs decisions but also drives meaningful change for communities around the world.

Lessons from the Private Sector

While public health is making strides in leveraging geospatial data and advanced analytics, there is much to learn from how the private sector has long utilized these tools for assessing and managing risk. Industries like insurance, supply chain management, and finance have developed robust methodologies to identify, quantify, and mitigate risks efficiently, offering valuable lessons for the health sector.

What Public Health Can Learn

In the insurance industry, geospatial data is foundational to risk assessment. Insurers routinely use these datasets to evaluate and visualize the likelihood of natural disasters, such as floods or hurricanes, and their potential impact on properties and populations. This granular risk analysis allows them to adjust premiums, produce risk-ratings for coverage areas, assess claims accurately, and even offer policyholders proactive measures to reduce their exposure to risks. This precision and foresight could greatly benefit public health agencies, especially in forecasting health crises or allocating resources to vulnerable populations.

Similarly, supply chain management relies heavily on geospatial analytics to ensure continuity and efficiency. For instance, companies use geospatial tools to monitor disruptions caused by extreme weather events, geopolitical instability, or infrastructure failures. By mapping out alternative routes or suppliers in real time, these systems mitigate risks and maintain critical operations. Public health could adopt similar approaches to safeguard medical supply chains, ensuring the uninterrupted flow of essential goods like vaccines, medications, medical supplies, and equipment during emergencies.

The finance sector also demonstrates the value of robust risk management processes. Investment firms analyze geospatial data to understand environmental, social, and governance (ESG) risks, identifying vulnerabilities that could impact long-term investments. This kind of predictive modeling could be invaluable for public health, helping agencies allocate funding and resources more effectively to prevent crises before they occur.

Bringing Private Sector Expertise to Health

The private sector excels at turning data into actionable insights, a skill that public health organizations well-served by adopting. For example, collaborations between geospatial technology companies and emergency management agencies led to the development of tools that combined satellite and areal imagery, real-time weather data, and evacuation patterns. These tools enabled officials to track fire progression, predict air quality impacts, and guide evacuation efforts. Such partnerships demonstrate how private sector innovation can enhance public health.

Another area of opportunity is leveraging the private sector's ability to standardize and scale analytics processes. Private companies have developed frameworks for data interoperability and efficiency that can be adapted for public health applications. For instance, adopting standardized geospatial data protocols or cloud-based analytics platforms could help public health agencies, community service, non-profits, and faith-based organizations streamline their operations and expand their analytical capabilities.

A More Robust Approach to Health Risk Management

Perhaps the most valuable lesson public health can learn from the private sector is the importance of having a comprehensive, proactive approach to risk management. Private industries prioritize identifying potential risks before they materialize, investing in tools and systems that allow them to respond swiftly when needed – or avoid the risk scenarios altogether. The health industry often focuses solely on reactive measures – addressing crises once they arise – and would benefit from incorporating more predictive and preventative strategies.

By adopting these practices, public health agencies can build more resilient systems capable of anticipating and mitigating health risks before they escalate. Whether it's forecasting the next disease outbreak, preparing for climate-related health impacts, or optimizing healthcare delivery during disasters, the health sector has much to gain by learning from the private sector's robust risk management processes.

Where Geospatial Intelligence Meets Impact

The integration of geospatial intelligence, SDOH data, and ML/AI techniques is reshaping the landscape of health risk analytics. These tools are no longer just about mapping data, they are transformative technologies that empower decision-makers to anticipate risks, allocate resources efficiently, and protect communities. By providing actionable insights rooted in location, context, and predictive analytics, GeoAI approaches are driving a paradigm shift in how we understand and manage health risks.

Achieving the full potential of these tools requires ongoing collaboration. The challenges of data curation, interoperability, and accessibility are not insurmountable, but they demand innovative thinking and cross-sector partnerships. Public health agencies, private sector leaders, and technology providers must come together to ensure that geospatial intelligence and health analytics are not only cutting-edge but also inclusive and impactful. This collaboration will bridge the gap between raw data and actionable insights, ensuring these technologies serve those who need them most.

At HSR.health, we are proud to lead the way in integrating geospatial technology into risk management. Our solutions demonstrate the power of combining diverse datasets with advanced analytics to create a holistic view of health risks. Whether it's predicting disease outbreaks, identifying communities at the greatest potential risk, or optimizing supply chains, we are committed to turning complex challenges into opportunities for meaningful action.