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Nationwide Analysis of Innovation Creation Sites and Flood Inundation Risk Using Japan's Patent Application Information from 1980 to 2018

Kuniaki Hamada[1*], Tetsuharu Oba[2], Junichi Susaki[1], and Yoshie Ishii[1]

[1] Graduate School of Engineering, Kyoto University,
Kyotodaigaku-katsura, Nishikyo-ku, Kyoto, 615-8540, Japan
[2] Graduate School of Management, Kyoto University,
Yoshida-honmachi, Sakyo-ku, Kyoto, 606-8501, Japan

Abstract Innovation drives economic growth and is more crucial than ever. However, despite Japan's susceptibility to natural disasters, particularly floods, it has not been clarified to what extent innovation creation sites are at risk of stagnation due to flood inundation. This study aims to evaluate the potential risk of flood inundation on innovation creation sites in Japan, using patent application information from 1980 to 2018 as a proxy for innovation creation. By overlaying spatial dataset of innovation creation sites and flood inundation risk areas, this study conducted spatiotemporal analysis to clarify the actual conditions of flood inundation risks on innovation creation sites on a nationwide scale. Approximately 40% of innovation creation sites (267,746 of the 715,997 sites in 2018) have flood inundation risks nationwide. The Osaka metropolitan area is particularly vulnerable because of the extensive flood inundation risk areas along the Yodo River. Furthermore, the study demonstrates increasing trends in the percentage of innovation creation sites with flood inundation risks in regional areas, highlighting a potential hindrance to future regional development. Additionally, Tokushima Prefecture has the highest proportion of innovation creation sites with flood inundation risks. These results offer valuable insights for a comprehensive understanding of the innovation vulnerability to flooding in Japan and provide perspectives to improve disaster preparedness measures from an innovation viewpoint.

Keywords. *Innovation, Flood inundation risk, Patent application information, Overlay analysis, Nationwide analysis*

* Corresponding author Name, E-mail address: hamada.kuniaki.68n@st.kyoto-u.ac.jp
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1 Introduction

1.1 Background and objective

Japan actively pursues innovation to sustain economic growth, enhance international competitiveness, and revitalize regions. Innovation drives economic development, transforms industrial structures, boosts regional competitiveness, generates jobs, and enhances quality of life. Recently, substantial investments in various sectors such as robotics, green energy, and information technology have realized significant strides in technology and research. These advances are essential not only for maintaining Japan’s position on the global stage but also for addressing domestic challenges, including an aging population and resource constraints.

Abnormal weather patterns over the past few years have increased the risk of natural disasters, especially floods. Typhoons, as well as localized heavy rains such as linear rainbands and sudden downpours, are becoming increasingly frequent. Floods have inflicted substantial damage on the country, raising concerns about their impact on industrial productivity and innovation creation. The impact of such disasters on innovation is particularly concerning because innovation is vital to sustained long-term economic growth. While there is a growing body of research on the effects of natural disasters on populations and households in Japan, little attention has been given to the risks that flood inundation poses to innovation creation sites. Globally, although there are several articles discussing the impact of floods on industrial activities and the role of innovation in flood risk management, research focusing on the relationship between natural disaster risks—particularly flood inundation risks—and innovation creation sites is limited.

This study aims to evaluate the potential risk of flood inundation on innovation creation sites in Japan. In addition to floods, Japan frequently experiences other natural disasters such as tsunamis and earthquakes. However, this study focuses exclusively on floods for the following two reasons.

First, flood risk has been increasing in recent years. According to AMeDAS (Automated Meteorological Data Acquisition System) observations by the Japan Meteorological Agency, the annual number of heavy rainfall events exceeding 50 mm has risen significantly. Over the past decade (2014–2023), the average annual occurrence was approximately 330, which is about 1.5 times higher than the average annual occurrence (approximately 226) during the first decade of the statistical period (1976–1985). This trend suggests a growing risk of severe floods in the country. A recent case occurred in Ishikawa Prefecture, where unprecedented rainfall in September 2024 caused significant damage. Several areas in the region, such as the cities of Wajima and Suzu, experienced rainfall levels that were double their usual monthly average in just one day. Rivers overflowed, isolating numerous communities, while landslides blocked roads and damaged infrastructure. Tragically, these events resulted in multiple fatalities and missing people. The heavy rainfall also inundated homes, including temporary housing for residents still recovering from an earthquake earlier in the year (Ng, 2024). This disaster highlights the increasing severity of flooding in the country.

Second, floods pose widespread risks across Japan. With approximately 70% of its landmass covered by mountainous or hilly terrain and characterized by steep slopes, Japan's geography exacerbates the risk of rapid water level rises during heavy rainfall, making floods and related disasters more likely to occur nationwide. In fact, over the past decade (2011–2020), approximately 98% of municipalities experienced water-related disasters, including floods and landslides (Ministry of Land, Infrastructure, Transport and Tourism, 2023).

For these reasons, this study focuses on floods and conducts a nationwide analysis of flood inundation risks at innovation creation sites. Here, patent application information from 1980 to 2018 is used as a proxy indicator for innovation creation. Specifically, overlay analysis is conducted to empirically identify the quantity and proportion of innovation creation sites at risk of flooding as well as the changes over time by metropolitan area and prefecture. This approach should quantify the vulnerability of innovation to flood inundation in Japan. It should also provide insight into the relationship between innovation creation and flood inundation risks from a spatiotemporal perspective.

1.2 Previous studies

In clarifying the potential risk of flood inundation on innovation creation sites, previous studies on flood inundation risk have mainly considered land use approaches to reduce natural disaster risks. The risk of flooding related to land use has become an urgent issue due to the increased severity of water-related disasters caused by heavy rains and typhoons in the wake of abnormal weather conditions. An increasing number of studies have focused on populations and households in flood-prone areas. For example, Qiang (2019) suggested that 21.8 million people (6.87% of the population) in the United States were exposed to a 100-year flood in 2015. They also found that economically disadvantaged populations are more likely to reside in flood zones. Ikram et al. (2024) assessed flood inundation risks in Afghanistan using a multimethod approach, which combined remote sensing, spatial analysis, and a literature review. They adopted the IPCC framework's hazard, exposure, and vulnerability indicators. Their study identified regions with significant exposure and vulnerability levels.

There are also several studies in Japan that have investigated natural disasters. Usui et al. (2023) suggested that a spatial disparity in flood inundation exists among households belonging to different annual income classes based on the Gini coefficient. Matsunaka et al. (2021) analyzed the population exposed to tsunami, earthquake, flood, and sediment disasters in 2010 and 2045 in Japan by metropolitan area and urban planning area classifications. Hada and Maeda (2020) showed that both the population and number of households within the flood inundation risk areas in Japan have consistently increased since 1995, which is likely due to increased residential land development in areas with high flood inundation risks.

On the other hand, a vast amount of research has been accumulated on innovation creation, and more studies are considering the factors that influence the status of innovation creation from a geographical perspective using patent application information. Rhoden et al. (2022) applied a functional data approach to mixture model–based multivariate innovation clustering, analyzing patent and economic data across 225 European regions over 13 years to identify regional innovation portfolios. Fan et al. (2023) used panel data from 285 Chinese cities and a difference-in-differences model to examine the impact of high-speed rail (HSR) on urban innovation. HSR significantly boosted innovation, especially in peripheral and small cities.

In Japan, Takeuchi et al. (2018) investigated the spatial characteristics of innovation. The geographic concentration trends of the network between innovation creation sites depended on the industry. Miwa et al. (2022) investigated how the introduction of HSR in Japan influenced patent applications over four decades. The implementation of the HSR system significantly increased innovation activities in regions along the HSR.

Thus, while there is an accumulation of research that focuses on either innovation creation or flood inundation risk, research that focuses on the relationship between the two is extremely limited, and at least there are no studies that focus on Japan. One of the few representative studies is Chen et al. (2021), which used a panel dataset consisting of 49 countries from 1985 to 2018 to quantitatively identify the association between natural disasters and innovation at the country level while controlling for endogeneity issues using the generalized method of moments (GMM). This was the first study to explicitly focus on the link between natural disasters and innovation. Natural disasters had a significant negative impact on innovation. The impact was not uniform across all types of natural disasters. Zhao et al. (2022) found that natural disasters could have a significant negative impact on energy technology innovation in 29 OECD countries. This impact was observed not only in the year that the natural disaster occurred but persisted for four subsequent years. Additionally, natural disasters were strongly and negatively associated with innovation in low-carbon energy technologies. Li et al. (2023) found that climate risks that cause natural disasters, including wind and flood disasters, negatively affected Chinese firms by reducing their investments and performances in innovation, especially in high-tech firms. The resultant decline in innovation due to climate risk also influenced a firm's value. Le et al. (2024) revealed that natural disasters negatively impacted R&D investment and subsequent innovation activities of firms in the United States. This impact persisted for up to three years following a disaster. Post-disaster financial constraints may reduce the incentive and motivation to innovate. Similar to this study, these studies used patent data to measure a firm's innovation. Patent data included the number of patents, the number of patent citations, and the number of citations per patent.

The few studies focusing on the relationship between innovation creation and flood inundation have clarified the impact on post-disaster innovation creation through data analysis and evidence. However, these studies have not focused on disaster risks that potentially cause delays or loss of innovation. They have not analyzed this relationship from a preventive perspective, nor have they empirically clarified the extent of flood inundation risks on innovation creation sites. To address these shortcomings, this study makes the following contributions:

- To clarify the vulnerability of innovation in each region, this study investigates the flood inundation risks on innovation creation sites on a nationwide scale.
- Using patent application information from 1980 to 2018, the study analyzes the long-term spatiotemporal variations in flood inundation risks on innovation creation sites.
- From a preventive perspective, this study provides critical insights to assess flood inundation risks before disasters occur and to implement appropriate measures.

2 Data and methodology

2.1 Patent application information

Patent applications from 1980 to 2018 were used to identify innovation creation sites in Japan. This approach is widely employed in empirical studies (e.g., Chen et al. (2021) and Miwa et al. (2022)) because it systematically provides information such as application date, inventor details, and industry category, which facilitates spatiotemporal analysis. However, it should be noted that patent application information may not perfectly represent innovation itself because not all innovations are patentable or intentionally patented.

Despite these considerations, the present study selected patent application information as a measure of innovation for two reasons. First, the number of samples is sufficient. Second, patent applications provide information suitable for spatiotemporal analysis. Furthermore, the inventor's addresses can be used to pinpoint the precise locations where research contributing to innovation is carried out because it is customary for inventors in Japan to register work addresses in the application.

More than 24 million samples of patent applications were collected from two databases: the Institute of Intellectual Property (IIP) Patent Database and the database offered by the Japan Patent Office (JPO). The IIP Patent Database covers patent application information in Japan from 1964 to 2019. This study utilized records in the IIP Patent Database from 1980 to 2012 because the available data is limited in older records and after 2013, inventor's address was omitted from the application. The JPO provided patent information from 2013 to 2018.

Both databases contain details like the inventor's name, address, and International Patent Classification (IPC). The databases also contained patent applications with inventor's addresses located overseas since individuals from other countries applied for patents through the JPO. Data from applications with overseas inventor addresses were excluded from this study as this research analyzed the vulnerability of innovation creation sites in Japan to flood inundation risks. After extracting the necessary patent application information, inventor's addresses were converted into latitude and longitude using an address matching service managed by The University of Tokyo. This allowed the data to be handled in GIS software.

Figure 1 compares the number of patent applications analyzed in this study with the number of applications published by the JPO. The number of patent applications analyzed in this study is lower than the actual number of applications published by the JPO. This discrepancy arises because the study excludes applications from overseas and those for which address matching was not possible. Nevertheless, the trends observed in the two datasets align closely over the years. Thus, the dataset employed in this study reliably reflects broader trends in patent applications.

In this study, each inventor is treated as an individual data sample, even in joint applications, under the premise that patents rely on the contributions of all inventors. Table 1 presents the number of samples by decade and area, and Figure 2 illustrates the number of samples when co-applicants are counted individually. In Figure 2, the data from 2016–2018 reveals a notably different pattern compared to other years. This deviation is likely attributable to an increase in joint applications during this period, which affected the counts when co-applicants were considered separately. However, as shown in Figure 1, the overall patterns in the two datasets are consistent across years, including the 2016–2018 period. Accordingly, the dataset used in this study can be regarded as a reliable representation of the general trends in patent applications.

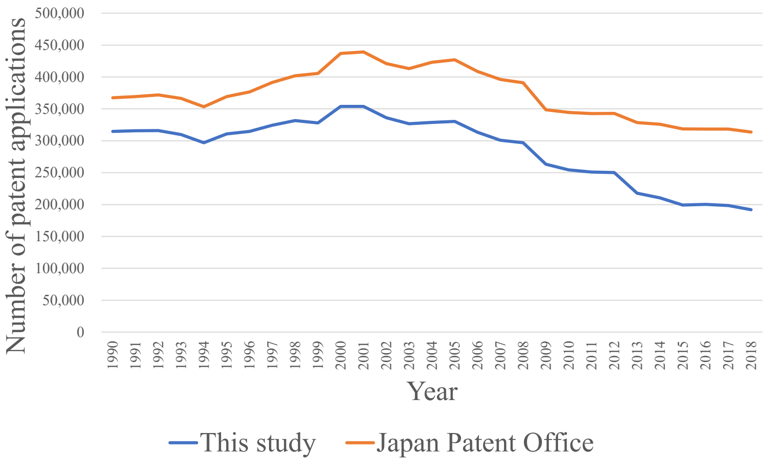

Figure 1. Comparison of number of patent applications used in this study and published by the Japan Patent Office

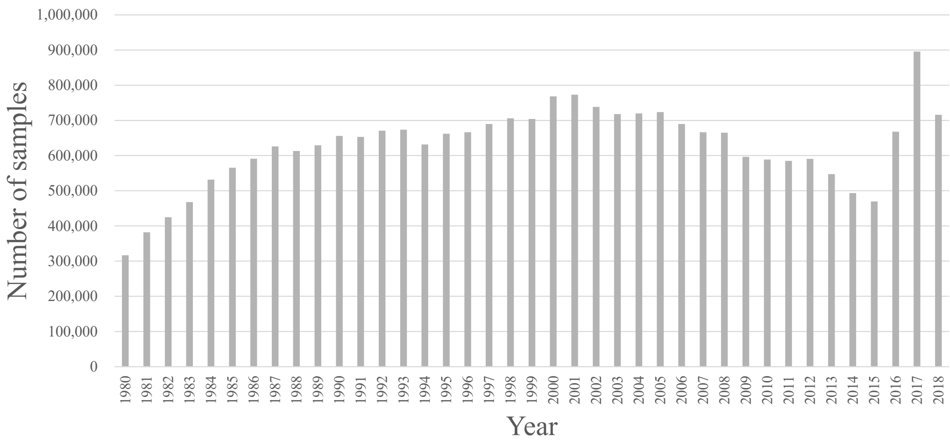

Figure 2. Number of annual samples used in the study

Table 1. Number of samples in each period by decade and area

Area	Period				Total
	1980–1989	1990–1999	2000–2009	2010–2018	
National area	5,148,452	6,714,161	7,058,867	5,554,184	24,475,664
Tokyo metropolitan area	2,605,275	3,359,017	3,488,043	2,829,417	12,281,752
Nagoya metropolitan area	340,947	539,735	686,967	739,832	2,307,481
Osaka metropolitan area	1,181,439	1,412,384	1,350,700	941,205	4,885,728
Regional area	1,020,791	1,403,025	1,533,157	1,043,730	5,000,703

2.2 Estimated flood inundation risk areas

The estimated flood inundation risk area data for Japan was sourced from the Digital National Land Information Site, which is administered by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). In this dataset, polygonal data represent the estimated flood inundation risk areas for major rivers designated by the national or prefectural governments. This format supports comprehensive nationwide risk analysis.

The risk areas included in the dataset suppose two types of flood conditions: L1 and L2 floods. L1 floods occur due to rainfall within a relatively short return period and serve as the standard for designing structures such as embankments and revetments. L2 floods occur due to the maximum conceivable rainfall with a relatively long return period. This research focuses on the risk areas for L1 floods since these occur more frequently and not all rivers in the dataset have L2 flood inundation risk data. However, it should be noted that the return periods of L1 floods vary by river. The data were arranged in five different years: 2012, 2019, 2020, 2021, and 2022. Each year's dataset includes only the data for that specific year. Consequently, this study utilizes risk area data from all five years by merging all polygonal data into a single layer for analysis.

Figure 3 shows the distribution of estimated flood inundation risk areas in Japan used in this study. Each polygon is assigned a water depth code, which indicates the projected inundation depth for that area.

There are slight variations in the categorization rules for water depth codes across the years and prefectures. To address this, a unified categorization rule for water depth codes was devised. By combining the rules from all years and prefectures into a single framework, the inundation depths are classified into three categories: less than 0.5 m, between 0.5 and 4.99 m, and 5 m or more. When risk areas for different rivers overlap, the overlapping area is assigned the highest inundation depth value among all overlapping polygons to analyze the worst-case scenario. Figures 4, 5, and 6 show the estimated flood inundation risk areas by flood inundation depth around the Tokyo, Nagoya, and Osaka metropolitan areas, respectively.

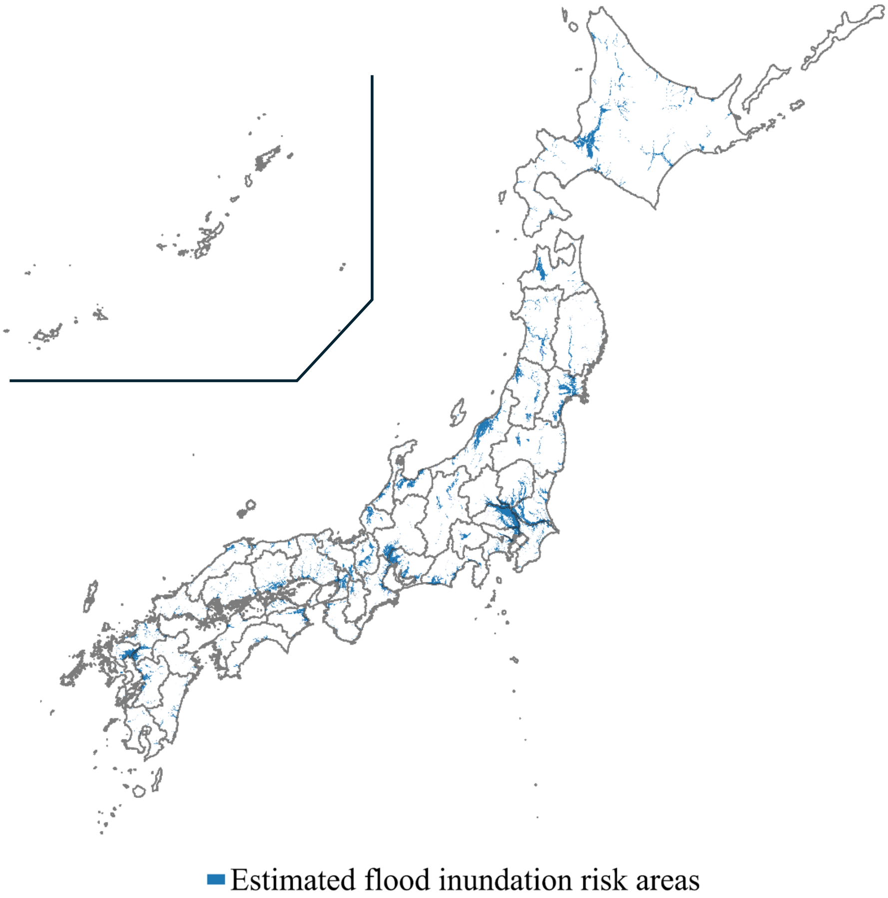

Figure 3. Nationwide distribution of estimated flood inundation risk areas

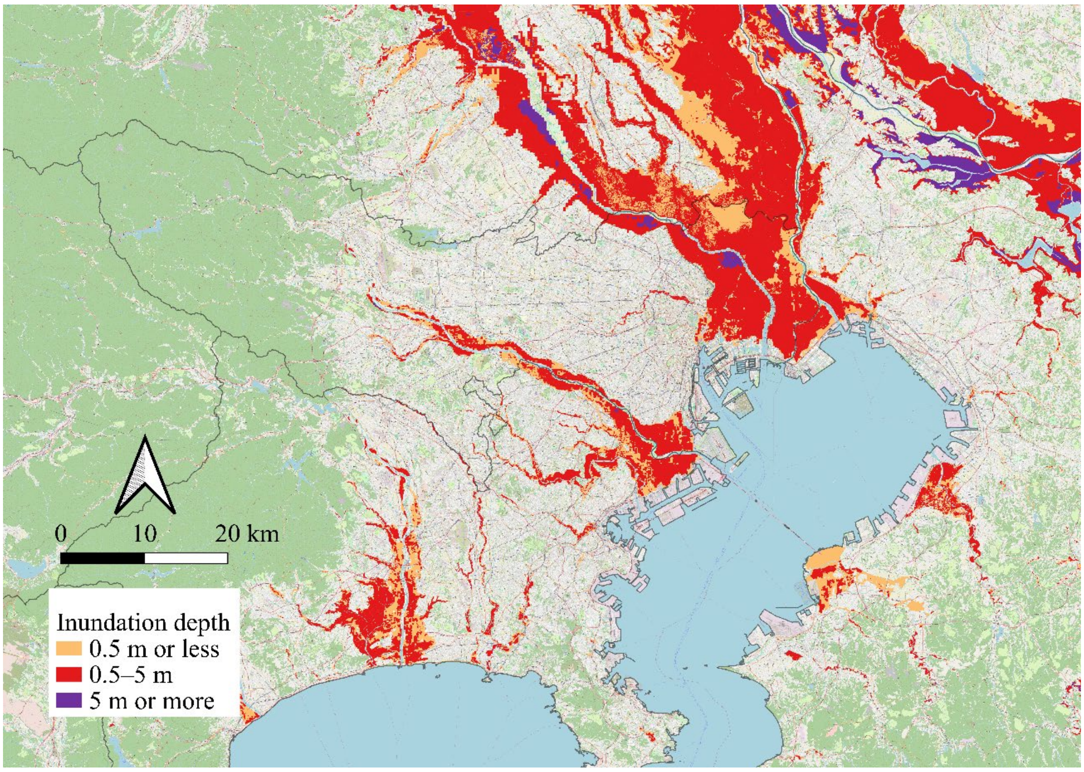

Figure 4. Estimated flood inundation risk areas by flood inundation depth in the Tokyo metropolitan area

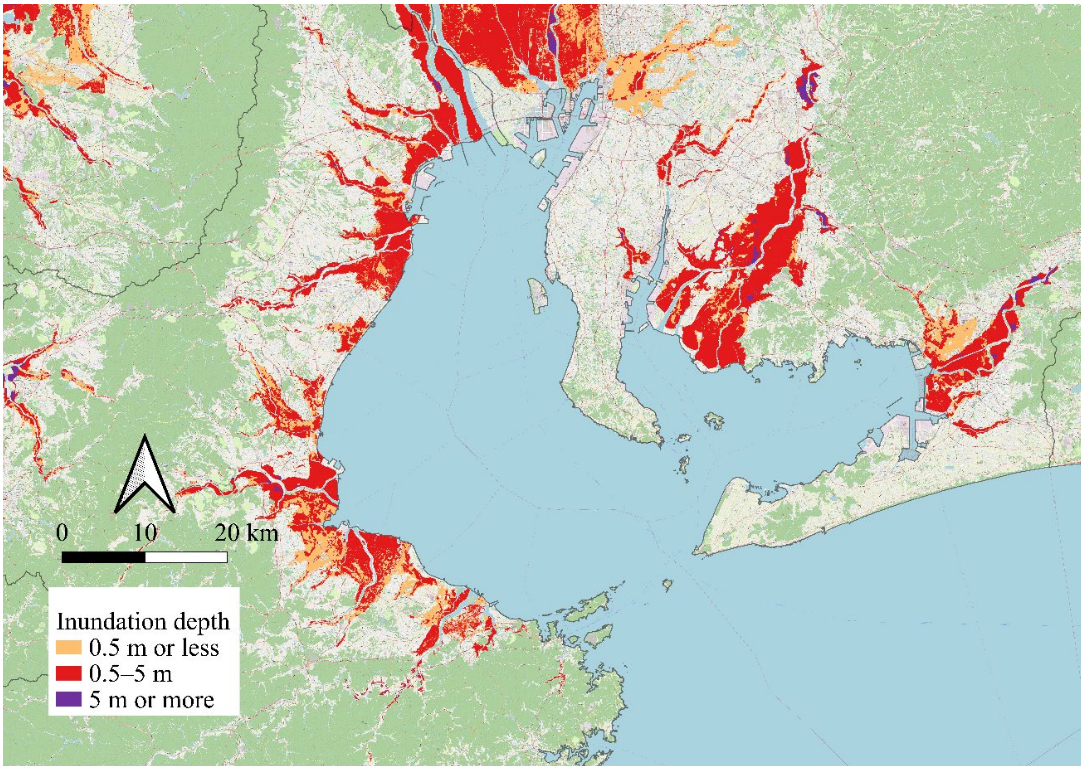

Figure 5. Estimated flood inundation risk areas by flood inundation depth in the Nagoya metropolitan area

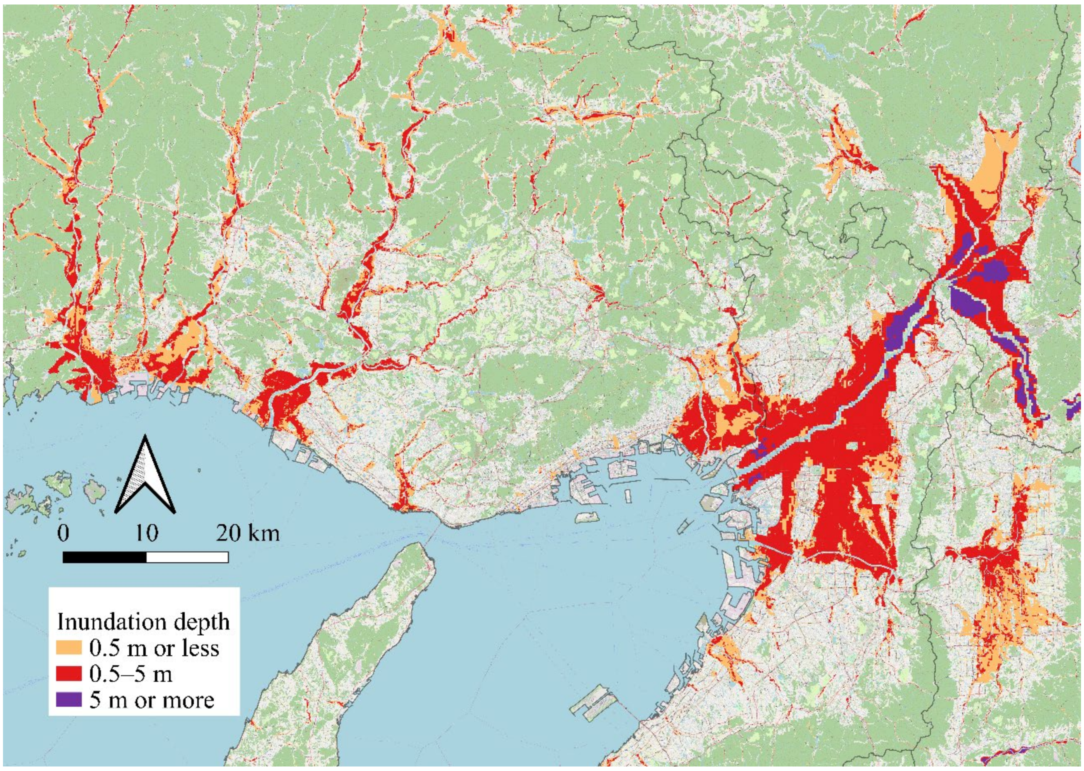

Figure 6. Estimated flood inundation risk areas by flood inundation depth in the Osaka metropolitan area

2.3 Overlay analysis

Innovation creation sites for each year were overlayed with the flood inundation risk areas in GIS software. The obtained results were quantified and visualized to grasp their characteristics. Innovation creation sites were classified as either inundated or not inundated. The former is within the estimated flood inundation risk area, while the latter is not. Inundated sites were further subdivided on the basis of inundation depth. Overlay analysis was conducted on a national scale. For clarity, Figures 7 and 8 depict the overlay analysis for the most notable region, which is around Shimane Prefecture and the Tokyo metropolitan area, respectively.

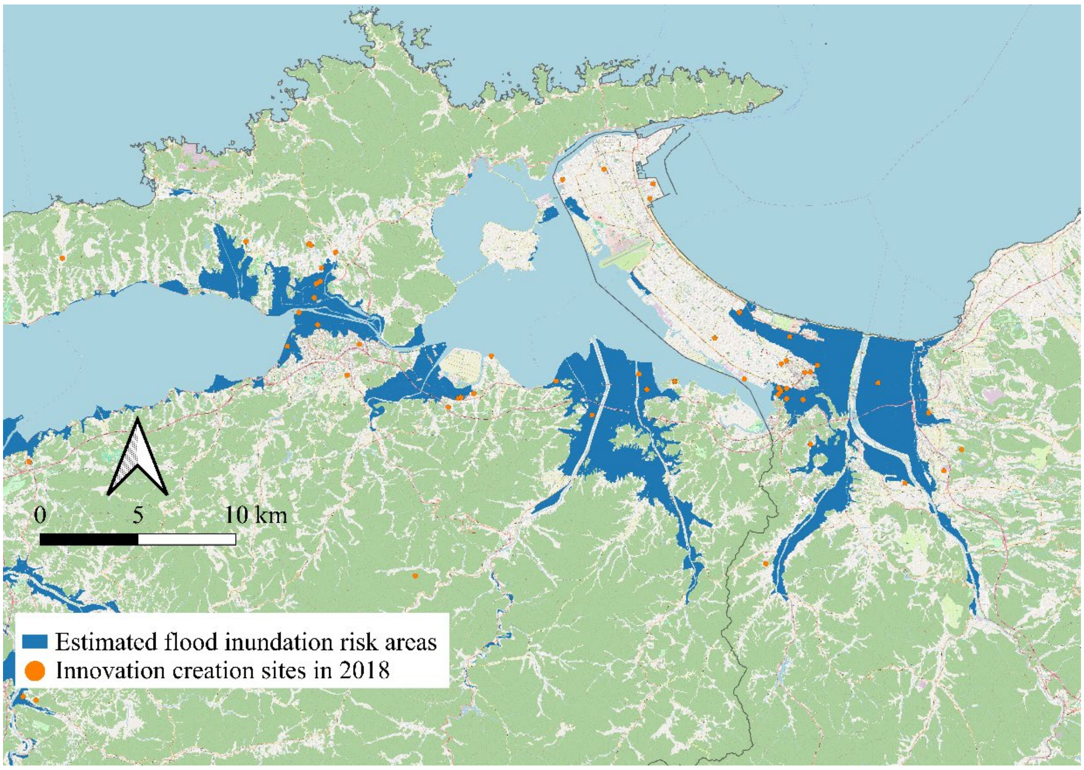

Figure 7. Overlay analysis of innovation creation sites in 2018 with estimated flood inundation risks in Shimane Prefecture

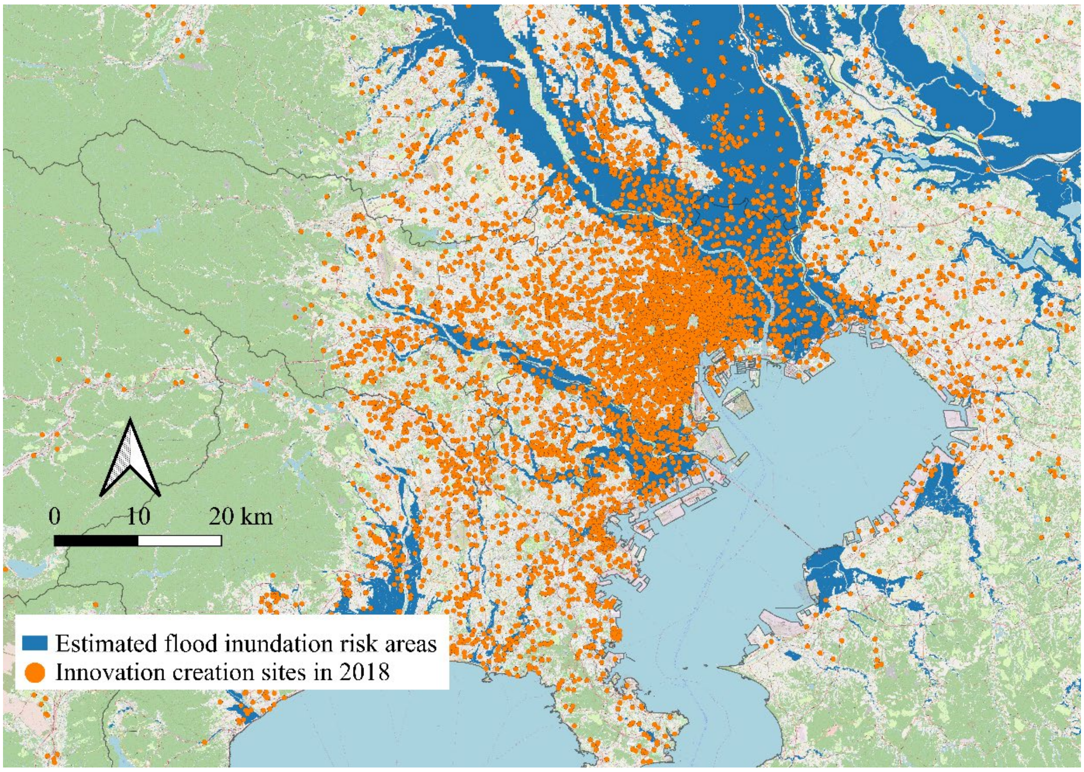

Figure 8. Overlay analysis of innovation creation sites in 2018 with estimated flood inundation risks in the Tokyo metropolitan area

3 Findings and discussion

3.1 Analysis of national, metropolitan, and regional areas

The vulnerabilities of innovation to flood inundation were analyzed in national, metropolitan, and regional areas. The Tokyo metropolitan area includes Saitama, Chiba, Tokyo, and Kanagawa Prefectures. The Nagoya metropolitan area is comprised of Mie, Gifu, and Aichi Prefectures, while the Osaka metropolitan area encompasses Kyoto, Osaka, Hyogo, and Nara Prefectures. Regional areas are defined as whole prefectures not included in any of the three metropolitan areas. Figure 9 shows the numbers and percentages of innovation creation sites in each area calculated by overlay analysis.

Although the percentage fluctuates over the years, approximately 40% of innovation creation sites in the national area have flood inundation risks. In 2018, 37.4% of innovation creation sites (267,746 of the 715,997 sites) were located in estimated flood inundation risk areas. The fact that approximately 40% of Japan's innovation creation sites are exposed to some flood inundation risk is too significant to ignore. The Tokyo and Nagoya metropolitan areas and regional areas have lower percentages of innovation creation sites with flood inundation risks, whereas the Osaka metropolitan area shows a much higher percentage throughout the years. In the Osaka metropolitan area, 66.3% of innovation creation sites (79,607 of the 120,086 sites) were in flood inundation risk areas in 2018. Furthermore, approximately 50% of innovation creation sites in the Osaka metropolitan area are in areas with an estimated flood depth of 0.5 m or more, which have the potential to cause severe damage. This is attributed to the large flood inundation risk areas for the Yodo River. Figure 10 demonstrates that many of the innovation creation sites in the Osaka metropolitan area are in estimated flood inundation risk areas. Consequently, the high number of innovation creation sites with flood inundation risks in the Osaka metropolitan area is a serious concern.

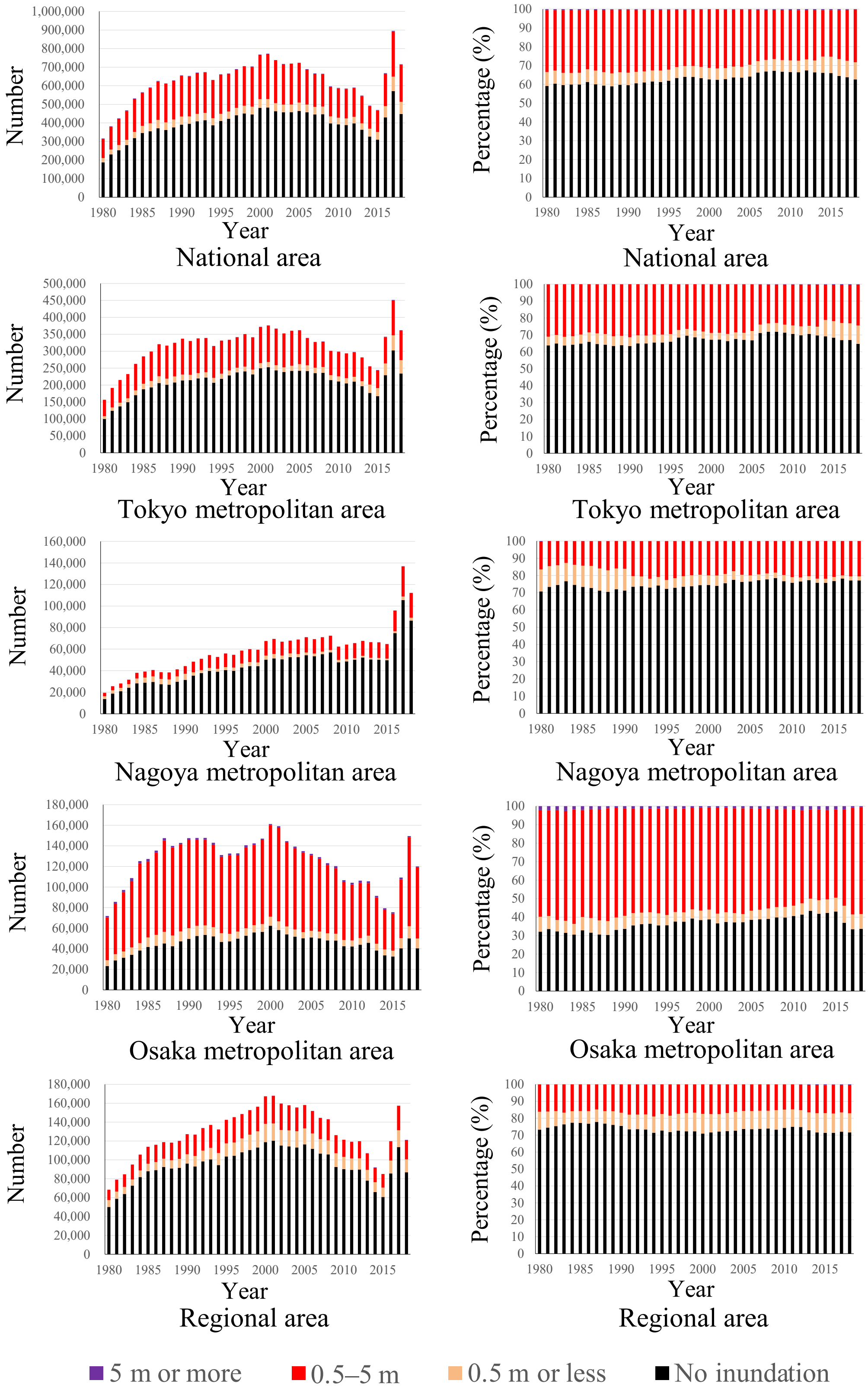

Figure 9. Annual number and percentage of innovation creation sites with estimated flood inundation risks by flood inundation depth

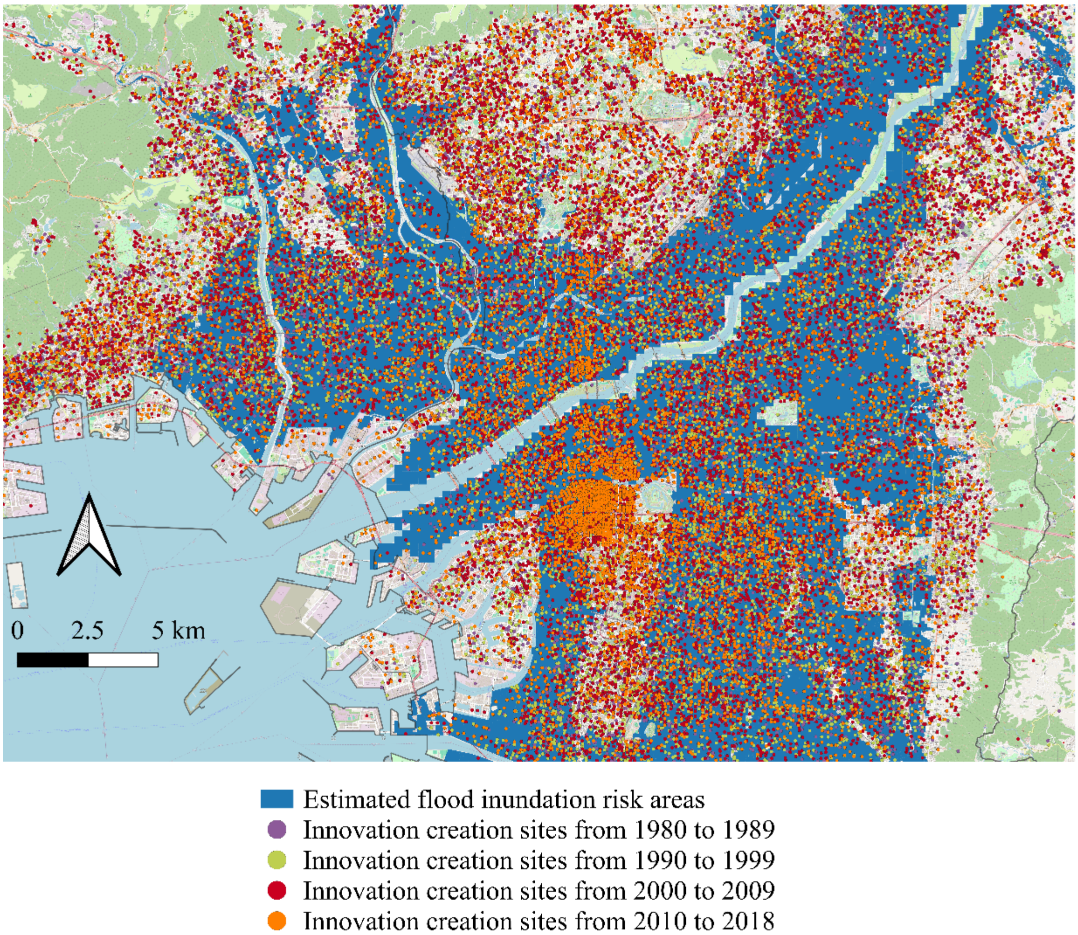

Figure 10. Innovation creation sites and the estimated flood inundation risk areas around the Yodo River in the Osaka metropolitan area

Figure 11 illustrates the change in the percentages of the innovation creation sites with flood inundation risks by inundation depth. The period was divided into four intervals to show the general trends for the same area: 1980–1989, 1990–1999, 2000–2009, and 2010–2018. The change in the percentages of innovation creation sites with flood inundation risks for a given area over time was calculated by dividing the percentages of the innovation creation sites for each period by the percentage for the 1980–1989 period. A value greater than 1 indicates that the percentage of the innovation creation sites with flood inundation risks has increased since 1980–1989. Conversely, a value less than 1 denotes that the percentage has decreased. A value of 1 indicates that the percentage of innovation creation sites with flood inundation risks has not changed since 1980–1989.

Previous studies have assessed flood inundation risk from the perspective of population and household numbers. By comparing the results of this paper with those studies, we can observe not only similar distribution characteristics but also different distribution patterns, providing intriguing insights.

For example, at the national level, the percentage of innovation creation sites without flood inundation risk shows an increasing trend over time. In contrast, Matsunaka et al. (2021) analyzed the population exposed to flood risks and found a declining trend in the population in areas without flood inundation risks at the national level. This suggests differing trends in flood risk exposure between innovation sites and population distribution.

In metropolitan areas such as Tokyo, Nagoya, and Osaka, the percentage of innovation creation sites exposed to flood risks shows a decreasing trend over time. On the other hand, in other regional areas, the percentage of innovation creation sites exposed to flood risks has slightly increased over the years. Specifically, in regional areas, a change of 1.150 is observed between 2010 and 2018. Matsunaka et al. (2021) similarly noted that outside the three major metropolitan areas, the proportion of the population exposed to floods tends to rise, whereas within the three major metropolitan areas, the proportion tends to decrease, indicating a reduction in disaster risk. This observed trend of increasing and decreasing populations in flood-prone areas across different metropolitan areas aligns with the findings of this study. Therefore, it suggests that the characteristics of the distribution trends for innovation and population in terms of flood risk are broadly consistent across various metropolitan and regional areas. This can be attributed to the fact that urban areas outside the three major metropolitan regions were created by converting farmlands, which are prone to flood damage. By contrast, the limited new development opportunities in the three major metropolitan regions drove development to hilly areas, as suggested by Matsunaka et al. (2018). This trend is likely to continue in the future. Thus, attention should be paid to innovation creation sites in the regional area.

Focusing on the flood inundation depth, it is evident that the proportion of innovation creation sites with an estimated flood depth of 5 m or more is significantly increasing in the Tokyo metropolitan and regional areas. In these two regions, a recent trend is the growing number of innovation creation sites concentrated in areas with very high flood disaster risks. Although the number of innovation creation sites in areas with an estimated flood depth of 5 m or more remains small compared to sites without flood inundation risks, the rising trend in these high-risk areas is noteworthy and demands attention.

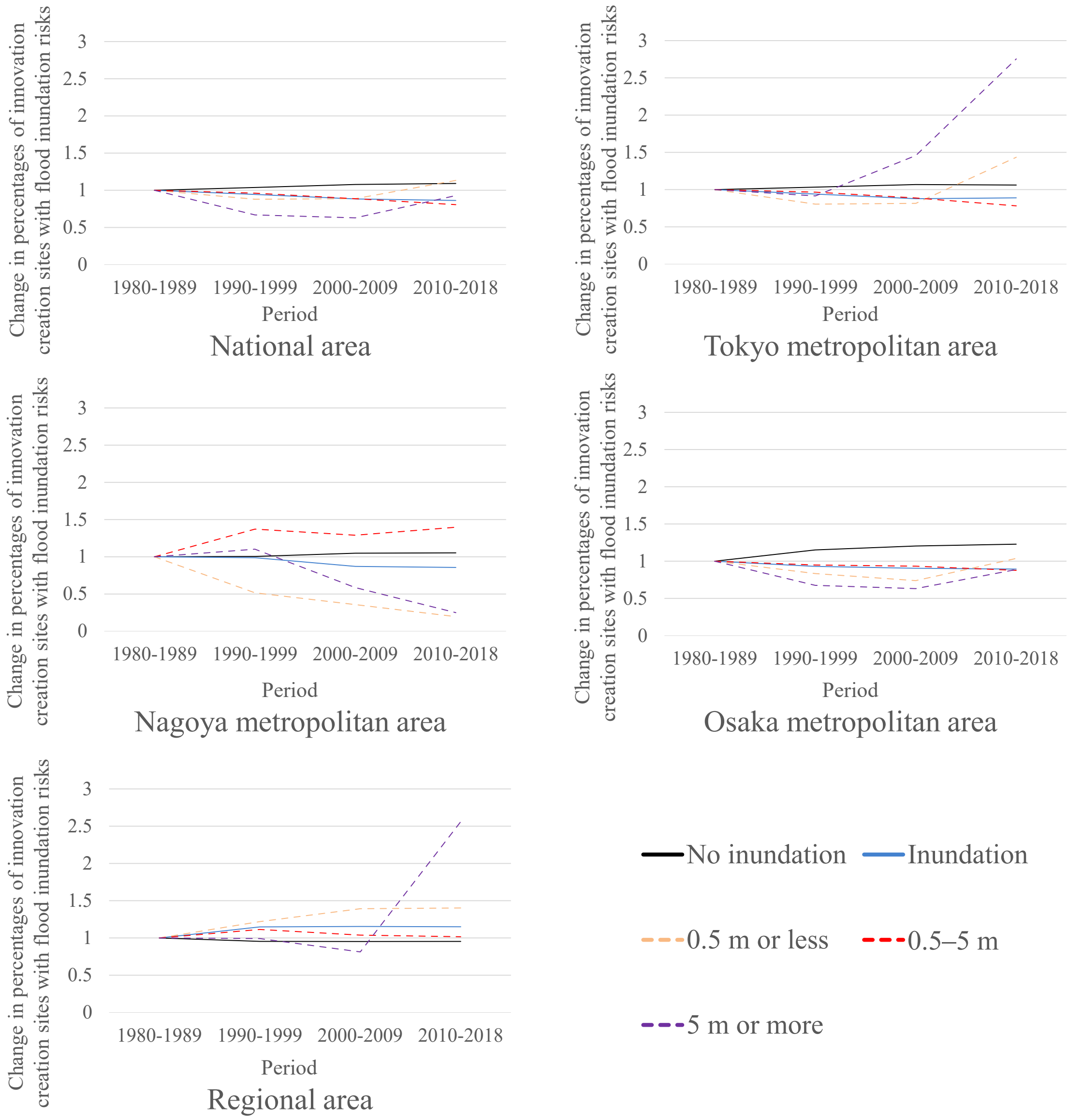

Figure 11. Change in percentages of innovation creation sites with estimated flood inundation risks by period and flood inundation depth

3.2 Analysis of prefectures

Figures 12 and 13 show the percentage of innovation creation sites with flood inundation risks by prefecture for the periods of 1980–1999 and 2000–2018, respectively. Tokushima Prefecture has the highest proportion of innovation creation sites with flood inundation risks. The percentages were 79.5% in 1980–1999 and 80.5% in 2000–2018. Figure 14 plots the actual distribution of innovation creation sites in Tokushima Prefecture from 2000 to 2018. Innovation creation sites are concentrated in the northeastern region of the prefecture. Because the northeastern region is near the mouth of the Yoshino River, many innovation creation sites are located within the estimated flood inundation risk areas. In prefectures with many innovation creation sites near rivers, there is a high need for caution because a flood could significantly impact numerous innovation activities at once. Additionally, the relatively high proportions of innovation creation sites with flood inundation risks in Osaka and Kyoto Prefectures suggest that these two prefectures are major contributors to the high proportion in the Osaka metropolitan area. These findings emphasize the need for targeted flood inundation risk mitigation strategies in these emerging hotspots to protect ongoing and future innovations.

To examine temporal changes, Figure 15 compares the ratio of the percentage of innovation creation sites with flood inundation risks by prefecture in 1980–1999 and 2000–2018. Values greater than, equal to, and less than 1 indicate that the percentage of the innovation creation sites with flood inundation risks has increased, remained constant, and decreased since 1980–1999, respectively. As a general trend, the proportion of innovation creation sites with flood inundation risk has decreased in many prefectures located along the Pacific Belt. By contrast, the proportion of innovation creation sites with flood inundation risk has increased in the Chubu area, the Tohoku area, and Hokkaido. This suggests that the increased proportion of innovation creation sites with flood inundation risks in the regional area is primarily driven by these specific regions. In such areas, the number of innovation creation sites is generally lower compared to the three major metropolitan areas. Regardless, regional areas with innovation creation sites with flood inundation risks may hinder future efforts toward local development.

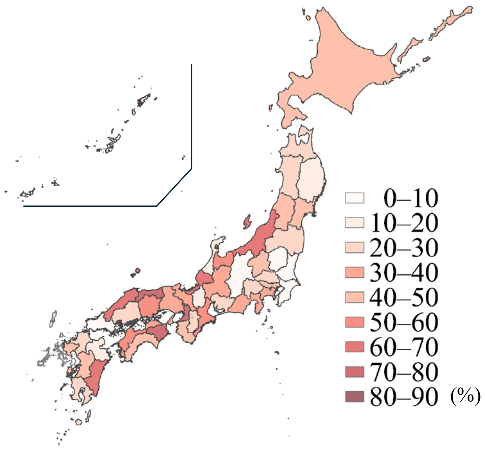

Figure 12. Percentages of innovation creation sites with flood inundation risks by prefecture from 1980–1999

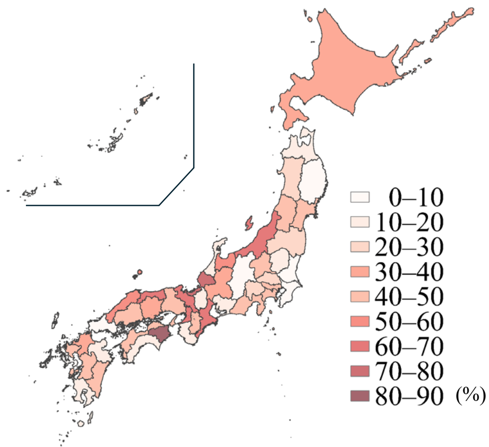

Figure 13. Percentages of innovation creation sites with flood inundation risks by prefectures from 2000–2018

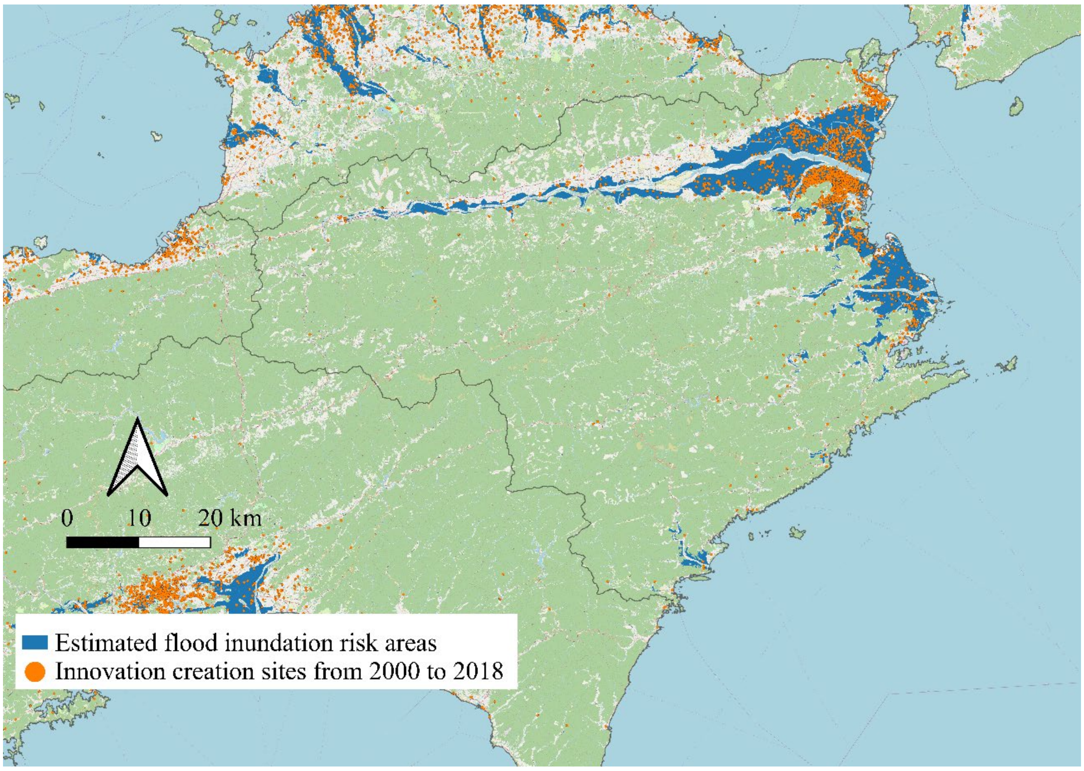

Figure 14. Overlay analysis of innovation creation sites from 2000 to 2018 with estimated flood inundation risks in Tokushima Prefecture

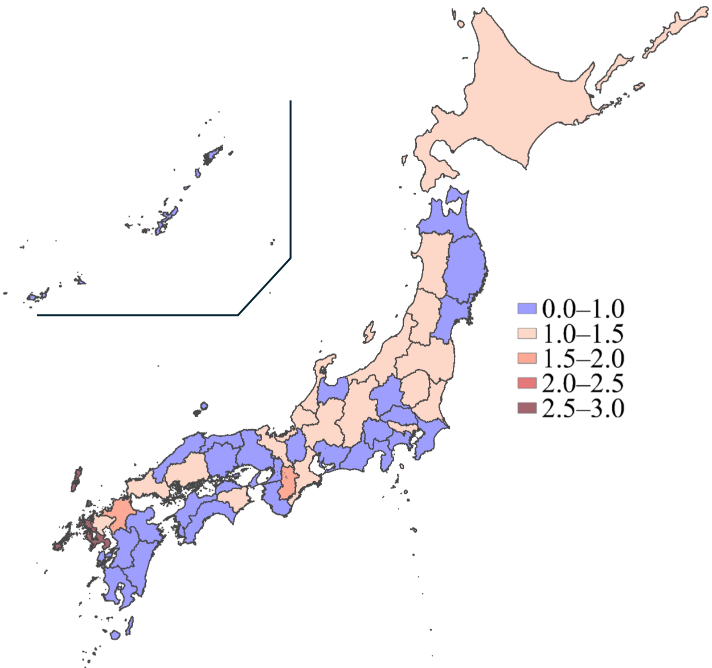

Figure 15. Ratio of the percentage of innovation creation sites with flood inundation risks in 2000–2018 to the percentage in 1980–1999 by prefecture

4 Conclusion

To provide insight into spatiotemporal trends, overlay analysis was used to assess the vulnerability of innovation creation sites to flood inundation risks in Japan from 1980 to 2018. A significant percentage of innovation creation sites have flood inundation risks nationwide. In particular, the Osaka metropolitan area is highly vulnerable due to extensive flood-prone areas along the Yodo River. Despite regional areas having fewer innovation creation sites than those in the three major metropolitan areas, the increasing trend of innovation creation sites with flood inundation risks suggests potential obstacles to future regional development.

Regions with a high proportion of innovation creation sites at risk of flooding were examined in each prefecture, and their temporal changes over time were assessed. Tokushima Prefecture has the highest proportion of patents in flood inundation risk areas. Additionally, temporal trends show a decrease in flood inundation risk proportions in some areas but an increase in others. For example, increasing trends are evident in the Chubu, Tohoku, and Hokkaido regions. These findings help elucidate the impact of disaster vulnerability on innovation in Japan and offer insight from an innovation perspective for future disaster preparedness measures at the nationwide and prefectural levels.

Although this study focused on analyzing the risk of flooding, Japan is prone to other natural calamities, including earthquakes, tsunamis, and landslides. Thus, for a comprehensive understanding of disaster risks on innovation, a broader investigation is necessary to encompass these threats. Such a study will provide a more general view of the challenges and vulnerabilities facing innovation in Japan.

Furthermore, discussing industrial classifications is also essential, as disaster risk management varies depending on the industry. For instance, growth industries with active innovation may require special risk management strategies, while industries that are particularly vulnerable to specific natural disasters need tailored risk assessments for their innovations. The patent application information used in this study includes International Patent Classification (IPC) details, which categorize technological domains. As shown in Table 2, these classifications cover a wide range of sectors. Future research could leverage these classifications to analyze how innovation in different industries exhibits varying patterns of flood risk exposure. For instance, patents related to agriculture in Section A may be more concentrated in areas with higher flood risks, as agriculture often relies on water from rivers, making these regions more vulnerable. In contrast, Section G, which includes patents related to nuclear energy, may have a lower proportion of research sites exposed to flood risks, as safety measures in this field may prioritize locating facilities in safer areas. Understanding disaster risk across various industries enables the development of industry-specific policies, which can contribute to strengthening the nation's sustainable innovation foundation.

Table 2. Description of International Patent Classification

Section	Subsection
A: Human Necessities	Agriculture
	Foodstuffs; Tobacco
	Personal or domestic articles
	Health; Life-saving; Amusement
B: Performing Operations; Transporting	Separating; Mixing
	Shaping
	Printing
	Transporting
	Microstructural technology; Nanotechnology
C: Chemistry; Metallurgy	Chemistry
	Metallurgy
	Combinatorial technology
D: Textiles; Paper	Textiles or flexible materials
	Paper
E: Fixed Constructions	Building
	Earth or rock drilling; Mining
F: Mechanical engineering; Lighting; Heating; Weapons; Blasting	Engines or pumps
	Engineering in general
	Lighting; Heating
	Weapons; Blasting
G: Physics	Physics
H: Electricity	Electricity

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