Jurnal Litbang:
Media Informasi Penelitian, Pengembangan dan IPTEK
http://ejurnal-litbang.patikab.go.id
Vol. 21 No. 1 Juni 2025 Hal 61-72

Utilization of GIS Ecosystem-Based Adaption with Community Participation in Flood Disaster Management in Pati Regency

Pemanfaatan SIG untuk Adaptasi Berbasis Ekosistem dengan Partisipasi Masyarakat dalam Pengelolaan Bencana Banjir di Kabupaten Pati

M Indra Hadi Wijaya[1) a)]*, Anang Wahyu Sejati[2) a)], Lutfia Diah Arsynindia[2) a)]*, Reinhart Christopher Junjungan[3) a)], Maman Kardiman[3) a)]

[1)] Perencanaan Wilayah dan Kota, Sekolah Vokasi, Universitas Diponegoro
[2)] Departemen Perencanaan Wilayah dan Kota, Universitas Diponegoro
[3)] Program Studi Magister Perencanaan Wilayah dan Kota, Universitas Diponegoro
[a)] Jl. Prof. Sudarto Kampus Tembalang, Kota Semarang. 50275. Jawa Tengah
*Email: indrahadiwijaya@live.undip.ac.id

Naskah Masuk: 20 Januari 2025 Naskah Revisi: 30 April 2025 Naskah Diterima: 21 Mei 2025

ABSTRAK

Daerah Aliran Sungai (DAS) merupakan bentang alam yang menyatu dan rentan terhadap bahaya seperti banjir, yang sering diperparah oleh faktor-faktor seperti perubahan tata guna lahan dan penanggulangan bencana yang reaktif. Penelitian ini menganalisis perubahan tutupan lahan dan hubungan spasialnya dengan daerah rawan banjir, menggunakan pendekatan Adaptasi berbasis Ekosistem (EbA). Pendekatan ini mengintegrasikan penginderaan jauh dengan metode partisipatif untuk mengurangi risiko bencana. Penelitian mengadopsi desain metode campuran, menggabungkan analisis spasial citra Landsat 8 (2000–2023) dengan data kualitatif hasil FGD, pemetaan partisipatif, dan wawancara yang melibatkan masyarakat lokal dan pemangku kepentingan pemerintah. Variabel-variabel utama yang dianalisis meliputi jenis tutupan lahan, luas spasial perubahan, kedekatan dengan sungai, elevasi, dan zona bahaya banjir yang telah dipetakan. Studi ini berfokus pada DAS Silugonggo di Kabupaten Pati, Jawa Tengah, sebuah daerah dengan risiko banjir tinggi. Hasil penelitian menunjukkan peningkatan signifikan pada area terbangun (menjadi 17,18%) dan penurunan tutupan vegetasi (luas hutan berkurang menjadi 7,57%), terutama di bagian tengah DAS, yang berkontribusi pada peningkatan limpasan dan risiko banjir. Keterlibatan masyarakat sangat penting dalam mengidentifikasi penyebab banjir lokal dan mengusulkan strategi adaptasi seperti reboisasi, zona penyangga riparian, dan sistem drainase yang lebih baik. Temuan ini menekankan pentingnya mengintegrasikan EbA dan partisipasi masyarakat dalam perencanaan pengurangan risiko bencana.

***Keywords**: banjir bandang, daerah aliran sungai, manajemen bencana, partisipasi masyarakat*

ABSTRACT

Watersheds are unified landscapes vulnerable to hazards like floods, often exacerbated by factors such as land-use changes and reactive disaster management. This study analyzed land cover changes and their spatial relationship to flood-prone areas using an Ecosystem-based Adaptation (EbA) approach. It integrates remote sensing with participatory methods to enhance disaster risk reduction. The research adopted a mixed-methods design, combining spatial analysis of Landsat 8 imagery (2000–2023) with qualitative data from focus group discussions (FGDs), participatory mapping, and interviews involving local communities and government stakeholders. Key variables analyzed included land cover types, spatial extent of change, proximity to rivers, elevation, and delineated flood hazard zones. The study focused on the Silugonggo River Basin in Pati Regency, Indonesia, a high-risk flood area. Results reveal a significant increase in built-up areas (to 17.18%) and a reduction in vegetation cover (forest area decreased to 7.57%), particularly in the midstream, contributing to increased runoff and flood risk. Community engagement was crucial in identifying localized flood causes and proposing adaptive strategies such as reforestation, riparian buffer zones, and improved drainage. These findings emphasize the importance of integrating EbA and community participation into disaster risk reduction planning.

***Kata kunci**: flash floods, watersheds, disaster management, community participation*

INTRODUCTION

Concerns about land-use/cover change emerged in the research agenda on global environmental change several decades ago. In the mid-1970s, it was recognized that land-cover change modifies surface albedo. In the early 1980s, terrestrial ecosystems as sources and sinks of carbon were highlighted (Lambin et al., 2003). The broader impacts of land use/cover change on ecosystem goods and services are further identified. Of primary concern are impacts on biotic diversity, soil degradation, the ability of biological systems to support human needs, and natural disasters (Twisa & Buchroithner, 2019).

Changes in land cover and use in an area occur not only in urban areas but are starting to occur in rural areas. Conversion of forest to agricultural or agricultural land is generally framed as an investment decision driven by the expected returns for alternative uses or appreciation of the value of the land in the future (Dias et al., 2016). Given the current state of land shifting from established agricultural landscapes to remote frontier areas, expectations regarding return on investment are based on very different socio-economic realities.

In mountainous watershed areas, agricultural land use leads to changes in ecosystem services, with trade-offs between crop production and erosion regulation. Intensive farming in these ecosystems reduces the ability to reduce soil loss in exchange for food production, and this worsens water quality downstream. Therefore, it is necessary to use land resources effectively under a land management plan, which is a region-specific policy to reduce trade-offs between ecosystem services (Sassolas-Serrayet et al., 2018).

One of the impacts of land use change is flooding in the downstream area of the watershed. On a global scale, flood zone urbanization trends are just as steep and increasing, especially in Africa and Asia (Winsemius et al., 2016). Not only has this meant more and more human assets are being flooded, but urbanization with increased impermeability and a lack of natural drainage is creating additional flooding problems where none existed before. Socio-economic changes are further exacerbated by an increase in extreme rainfall caused by climate change, which amplifies the intensity and likelihood of flooding (Jongman, 2018).

An ecosystem-based adaptation approach is needed for regional and urban planning and for addressing the impact of land change in the watershed from upstream to downstream. Ecosystem-based adaptation refers to 'the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the effects of disasters' (Nalau, Becken, & Mackey, 2018a). EbA covers the conservation, restoration, and sustainable management of ecosystems, ecosystem processes, and biodiversity to address the impacts of climate change on people's lives and livelihoods (Donatti et al., 2020).

Community involvement or participation can be interpreted as the involvement or inclusion of individuals and the general public physically and non-physically (Ismail, 2019). Besides that, broad community involvement is a form of community participation and involvement either actively or voluntarily from within (intrinsic) or from outside (extrinsic). The community-based approach to disaster preparedness is an increasingly important element of vulnerability reduction and disaster management strategies (Allen, 2006). This strategy relates to policy trends that value the knowledge and capacities of local communities and build on local resources, including social capital (Newport & Jawahar, 2001).

Recognizing the important role of local communities in hazard identification and assessment, the use of hazard mapping with Geographic Information Systems (GIS) is utilized. It is essential to integrate local knowledge, GIS, and maps into the disaster risk management process. There are three main reasons for this integration: (i) hazard maps play a key role in disaster risk identification and are an effective tool for making local knowledge visible; (ii) local knowledge is essential for disaster risk management; and (iii) GIS maps have advantages over conventional maps (Tran et al., 2009).

Community participation-based disaster management approaches through GIS and EbA have been carried out by several researchers, but most of them have separate themes. For instance, the application of participatory mapping through GIS often involves a lot of modeling as a result of land conversion (Ntajal et al., 2017; Tran et al., 2009; Twisa & Buchroithner, 2019; White et al., 2010). In contrast, analyses of EbA in disaster management tend to focus more on flood disasters resulting from climate change (Indonesia, n.d.; Nalau, Becken, & Mackey, 2018b; Sultana et al., 2023). This study examines the community's response to disaster management by providing mapping based on GIS analysis results, as well as combining the application of EbA from upstream to downstream of rivers affected by floods.

As one of the developing regions along the northern coast of Java (Pantura), Pati Regency is experiencing increasing demand for space to support various socio-economic activities, including housing, industry, and services. This development trajectory, while contributing to economic growth, is also accelerating the transformation of land use, particularly in peri-urban and agricultural zones. According to data from the National Land Agency (BPN) and the Pati Regency Land Office (2021), there has been a notable increase in land use status changes, particularly involving the conversion of productive agricultural land into residential yards.

In 2020, approximately 200,845 square meters of land were converted from rice fields to yards, and 79,942 square meters from dry fields (tegalan) to yards. This trend reflects the growing pressure on land use driven by the expansion of settlements and infrastructure. The trend intensified in 2021, with 334,112 square meters of rice fields and 417,070 square meters of dry fields converted into yards (Kabupaten Pati, 2021). This research will identify and analyze the role of community participation in flood disaster management in Pati Regency, Central Java Province, Indonesia. Current flood management strategies remain reactive, with limited integration of proactive, ecosystem-based approaches and participatory methods involving local communities. Specifically, this study seeks to answer: How have land use changes, particularly in flood-prone areas, contributed to increased disaster risk in Pati Regency, and how can ecosystem-based and participatory approaches enhance flood mitigation? Furthermore, this research can contribute to the growing discourse on nature-based solutions by demonstrating how spatial analysis and community engagement can support ecosystem-based adaptation (EbA) in flood-prone areas.

INTRODUCTION

Geographic Information Systems (GIS)

Geographic Information Systems (GIS) have been widely used in disaster management, including in ecosystem-based adaptation. GIS allows for the collection, analysis, and visualization of spatial data to support better decision-making. According to Prasetyo et al. (2021), the use of GIS helps in mapping flood-prone areas and identifying natural ecosystems that can be utilized for risk mitigation. Ecosystem-based approaches, such as wetland restoration and mangrove forest management, can increase the adaptive capacity of ecosystems and surrounding communities to disaster threats. GIS is also an important tool for mapping social and ecological vulnerabilities, which form the basis for more holistic and effective adaptation planning (Andini & Setiawan, 2020).

In addition, Cutter et al. (2003) emphasize how GIS allows for spatially explicit vulnerability assessments by integrating exposure, sensitivity, and adaptive capacity indicators. Goodchild (2006) underscores the significance of spatial data infrastructures in facilitating real-time coordination and decision support during disaster events. Regionally, in Southeast Asia, the application of GIS has been particularly effective in flood hazard zoning and early warning systems. For instance, Niu et al. (2020) demonstrate the utility of GIS-based multi-criteria decision analysis (MCDA) for prioritizing flood mitigation interventions in rapidly urbanizing areas. These combined applications highlight GIS not only as a technical instrument but also as a bridge between environmental data, local knowledge, and adaptive governance in disaster risk management.

Land Use Change and Flood Risk

Land use change, particularly due to rapid urbanization and deforestation, has been widely recognized as a key driver of increased flood risk, especially in low-lying and riverine regions. Urban expansion typically leads to the conversion of natural land covers—such as forests, wetlands, and agricultural land—into impervious surfaces like roads, buildings, and pavements, which significantly reduce water infiltration and increase surface runoff. Dewan et al. (2012) demonstrated through remote sensing analysis in Dhaka, Bangladesh, that a notable increase in built-up areas contributed directly to higher flood frequency and severity due to the loss of natural drainage systems and permeable surfaces.

Abhas et al. (2010) emphasize that unplanned urban growth without corresponding investments in drainage infrastructure has exacerbated flood impacts in many Asian cities. This is particularly problematic in rapidly developing countries, where land use planning often lags behind urban expansion. In the context of Indonesia, Rimba et al. (2017) provide evidence from the Upper Ciliwung River Basin, showing how deforestation and land cover change upstream significantly affected downstream hydrology, intensifying flood events in Jakarta. Their study highlights that vegetated areas play a critical role in water retention and the delay of runoff, which are essential in regulating watershed-scale flood risk.

Community Participation

Community participation is a crucial aspect of the ecosystem-based adaptation approach to flood management. Involving local communities in spatial data collection, such as participatory mapping, can improve data accuracy and strengthen community awareness and adaptive capacity. A study by Lestari et al. (2019) showed that participatory mapping through GIS allows communities to identify priority areas for protection and propose ecosystem-based solutions appropriate to local conditions. In addition, integrating GIS with local knowledge provides an opportunity to create more inclusive and adaptive strategies for climate change and flood risk. Therefore, collaboration between modern technologies such as GIS and local community knowledge is key to implementing sustainable ecosystem-based adaptation.

The success of ecosystem-based adaptation in flood-prone areas is largely influenced by several key independent variables, notably the application of Geographic Information Systems (GIS), the extent of community participation, and the types of ecosystem-based approaches implemented. The use of GIS plays a vital role in collecting, analyzing, and visualizing spatial data, which supports more informed decision-making in disaster risk management. Through GIS, flood-prone zones can be accurately mapped, and natural ecosystems with mitigation potential identified. In parallel, community participation significantly enhances the effectiveness of these efforts. Local involvement in spatial data collection, particularly through participatory mapping, not only improves data accuracy but also empowers communities to contribute local knowledge and propose context-specific solutions. Furthermore, the implementation of ecosystem-based strategies, such as wetland restoration or vegetative buffer zones, directly contributes to increasing the adaptive capacity of both the environment and local resident. Together, these variables form the foundation for sustainable and inclusive flood management strategies.

RESEARCH METHODS

This study adopts a mixed-methods design, integrating quantitative spatial analysis with qualitative data from field observations and interviews. Data collected by spatial data: Landsat 8 imagery (2000 and 2023), administrative boundaries, flood-prone area maps from BNPB, and by Ground Truthing & Institutional Data: Interviews with officials from BPBD Pati, Bappeda, and village representatives supported by field observation of flood-prone locations .

The research study area focuses on Pati Regency. Pati Regency is one of the districts located in Central Java Province, Indonesia (Figure 1). Pati Regency borders directly on the north coast of the Java Sea. This area includes the Juwana watershed. The data used in this study included land cover change data processed from Landsat 8 satellite imagery with a 30 m resolution, taken from three time series (2000, 2010, and 2023). This was followed by community involvement data gathered through a primary survey in Pati Regency. The data were then grouped based on administrative areas with river characteristics from upstream to downstream that have been affected by flooding. To deepen the understanding of local dynamics and stakeholder perspectives, Focus Group Discussions (FGDs) were conducted with key stakeholders, including representatives from local government agencies, disaster management bodies, and environmental offices—as well as with community members residing in flood-prone areas. These FGDs aimed to capture qualitative insights on community experiences, perceptions of flood risk, and their involvement in ecosystem-based and participatory approaches. In addition, other supporting data, such as regional policies related to disaster risk assessment and disaster management plans, were also utilized.

Methods

Risk assessment is based on two aspects of spatial issues: physical and socio-economic. The physical aspect is analyzed from physical and environmental vulnerability and disaster hazards. Several sources of spatial data come from InaRisk (Indonesian Disaster Geoportal) (Indonesian Disaster Mitigation Agency, 2012). The socio-economic aspect, on the other hand, is analyzed from socio-cultural and economic vulnerability, as well as regional resilience and disaster preparedness. The social aspect is obtained through a participatory mapping process, which allows for accurate mapping of community capacity, thereby describing the level of regional resilience.

Remote Sensing Analysis:

- Supervised classification with Maximum Likelihood Algorithm conducted using QGIS and SNAP.
- Change detection over 10 years (built-up, agriculture, water body) combined with flood-prone map layers.

This research begins by analyzing the pattern of land cover change, which was carried out using GIS for the period 2000-2023 through a guided classification analysis tool. The results of this analysis include the patterns and amounts of land change, followed by identifying the locations of flood disasters in relation to these land cover change patterns.

Figure 1.
Study Area

Qualitative Analysis:

Thematic analysis was conducted on interview transcripts using manual coding to extract insights on institutional capacity, decision-making, and GIS application. The next stage involves identifying the community's role in the mapping results. At this stage, we tested the causes of disasters and the community's understanding of EbA, followed by recommendations for disaster management planning needs.

In this regard, the village serves as a forum for ensuring public participation in mapping village boundaries. This is crucial because local community knowledge is needed as primary data in land use planning. Furthermore, the participatory approach is a method accepted by the community as a strategy that can ensure community contributions to mapping. Therefore, the local knowledge shared by the village in the FGD can strengthen and confirm the results of data collected in the field by surveyors. If there is a dispute in the determination and affirmation of village boundaries, the FGD method can help find a solution to the problem.

RESULTS AND DISCUSSION

Land Cover Change and Flash Flooding

Indonesia is a country located in Southeast Asia and is prone to a wide range of natural disasters due to its geographical location, which includes being part of the Pacific Ring of Fire and having extensive coastlines. The country's complex geology and diverse climate create conditions conducive to various natural hazards, such as hydrometeorological disasters, especially in the northern coastal region of Java Island (Buchori et al., 2018). This disaster vulnerability is further exacerbated by land use conversion, particularly in areas like the North Coast of Central Java. For instance, in Koto Regency, the built-up area has a growth rate of 12% per year, with 37% of this built-up area showing scattered growth and an irregular development pattern (Dewa et al., 2022).

Pati Regency still has 1178.32 hectares of Protected Forest spread across the slopes of Mount Muria. Protected forests have an important function in preventing disasters such as floods, landslides, droughts, and flash floods. Residential land use is vulnerable to disasters because it encompasses all human activities, including educational, trading, industrial, and other activities. If a disaster occurs in residential areas, the potential for population exposure is very high, which can hamper all activities, including economic, educational, industrial, and transportation.

The dynamics of land cover in a watershed are known to influence disaster occurrence, increasing the urgency to observe these dynamics as an effort to mitigate natural disasters. Within Pati Regency's watersheds, which are part of the Jratunseluna River Basin, agricultural land cover consistently has the largest area compared to other types of cover. Bare land, on the other hand, consistently has the smallest area. This cover has gradually declined over the past three decades.

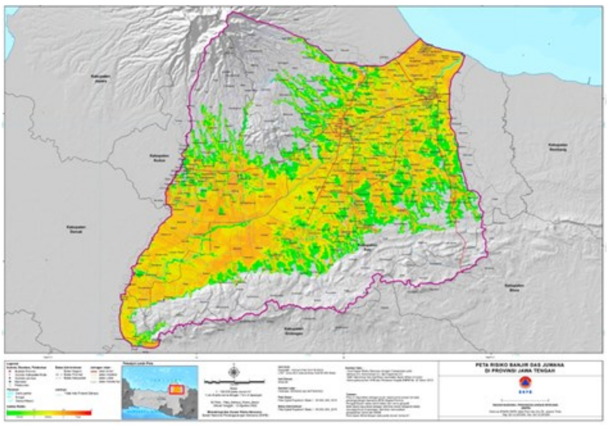

Figure 2.
DAS Juwana/Sungai Silugonggo

Pati Regency, located in the northern part of Central Java Province, is also experiencing conditions of land use change and land cover. As shown in Figure 2, the results of the guided analysis using GIS from 2000 to 2023 reveal a 66.88% growth in built-up land throughout the Pati Regency area. This condition occurs because the expansion of urban areas leads to the north and east of Pati Regency. Meanwhile, forest area decreased by 7.15% and agricultural land decreased by 1.80%. This condition is in line with the growth of built-up areas in Pati Regency.

This indirectly contributes to the flash floods that occurred in Pati Regency, especially in the Silugonggo River basin. Based on the disaster risk study analysis from BNPB (National Disaster Management Agency) Juwana Watershed in 2022, information regarding the potential risk area in the Juwana Watershed totals 84,526.69 Ha. The highest risk area is in Sukolilo District, Pati Regency, covering 8,639.36 Ha, with low-class areas at 1,350.38 Ha, medium-class areas at 5,929.62 Ha, and high-class areas at 1,359.36 Ha. The lowest risk area is in Trangkil District, Pati Regency, at 3.11 Ha, where all risk areas are in the low class.

This river basin has headwaters on Mount Muria to the east in the Gunungsari area and empties into the Bulumanis and Juwana areas. The results of satellite imagery identification, followed by field verification carried out through mapping using drones with samples in the upstream, middle, and downstream areas of the Silugonggo River basin, revealed that the upstream part of the river in the Gunungsari area had not experienced significant land change. The land was still being used for coffee plantations and pine forests. In the central part of the watershed, there has been a change in land use, especially on the riverbanks where, in 1990, it was still planted with perennial crops. However, from 2010 to the present, it has changed to annual crops such as cassava. This condition exists because Pati Regency is one of the second-largest cassava-producing areas in Central Java after Wonogiri Regency. The area of cassava land in 2015 was 17,781 ha, and the productivity was 744,746 kw/ha (Luthfiah et al., 2017).

Previous studies have found that built-up land cover is more vulnerable to disasters. Densely populated activities carried out on built-up land can increase the losses incurred when a disaster occurs. Conversion of land cover from canopied vegetation to agriculture can also increase disaster vulnerability. The inferior ability of agricultural crops to bind the soil and absorb water compared to canopy vegetation is also known to increase disaster vulnerability. Floods, flash floods, and landslides are known to be affected by the condition of the land cover their shelter.

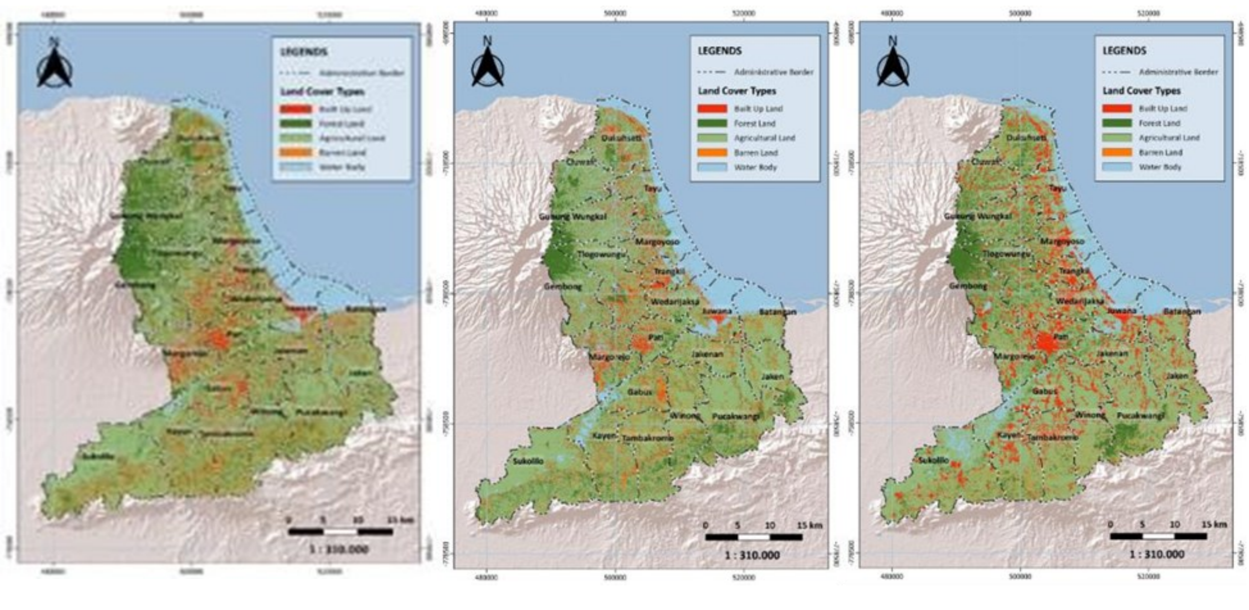

Figure 3.
Land Cover Change 2000-2023 in Pati Regency

Flood conditions due to changes in land use and cover are also influenced by topographic conditions, not only seen from the slope of the slopes but also through altitude. The altitude of a place will affect the potential for inundation. As much as 12.88% of the Pati Regency area has an elevation of less than 5 meters above sea level, making it prone to flooding, especially during the rainy season. On the other hand, there are 23 watersheds in Pati Regency, with the Juwana watershed being the largest. The Juwana Watershed has an area of 90,776.82 hectares and a river length of 62.8 km. The Juwana River often overflows and causes floods. This phenomenon contributed to 15 flood events that occurred in 2020 (BPDAS Pemali Jratun, 2022a). Findings from BPDAS Pemali Jratun (2022b) indicate that most of the protected areas in the Juwana watershed had 97.42% vegetation cover with a "very good" classification. However, the assessment of vegetation cover (PPV) analysis shows that the area of permanent vegetation in the Juwana Watershed is in the "poor" category (29.1%). This suggests that the permanent vegetation cover is not proportional to the size of the Juwana watershed according to the PPV standard.

Meanwhile, in the lower reaches of the river, within urban areas, land use changes are mostly characterized by residential building development. Housing growth began in early 2010 with the emergence of cluster-type housing scattered in the urban areas from Pati to Juwana Districts. Here, the river experiences siltation, sedimentation, and narrowing of its cross-sectional area. Coupled with high rainfall, this results in flooding and flash floods (most of the rivers in Pati Regency experience physical changes, such as the river body narrowing in their lower reaches). These conditions occur in the Gung Wedi, Simo, Sani, Silugonggo, Suwatu, Gung Wedi, and Godo Rivers. These disturbances arise due to the dumping of garbage into the river and boat parking. The villages of Bulumanis Kidul (Margoyoso Sub-district), Ngurenrejo (Wedarijaksa Sub-district), and Sinomwidodo (Tambakromo Sub-district) are examples of areas damaged by floods and flash floods. This condition is exacerbated by changes in land use from forests to agricultural activities, which reduce the ability to mitigate floods and flash floods.

Flood conditions, due to changes in land use and cover, are also influenced by topographic conditions, not only considering the slope of the land but also its altitude. The altitude of a place will affect the potential for inundation. As much as 12.88% of the Pati Regency area has an elevation of less than 5 meters above sea level, making it prone to flooding, especially during the rainy season. On the other hand, Pati Regency has 23 watersheds, with the Juwana watershed being the largest. The Juwana Watershed spans an area of 90,776.82 hectares with a river length of 62.8 km. The Juwana River is a river that often overflows and causes floods. This phenomenon contributed to 15 flood events that occurred in 2020.

Level of Community Participation

The community involvement process in mapping potential disasters and management plans is carried out through the FGD process. Community participation plays a very important role in ensuring the availability of appropriate field data. In this case, community participation regarding the mapping of potential disasters and causes of flooding is urgently needed, especially the information provided by the village to the people living in the location. The village authorities can provide an overview that represents the knowledge of the local community (Cahyono et al., 2020; Wahyuni et al., 2020). The implementation of participatory mapping was carried out in June 2023 throughout the Pati Regency area. Detailing land conversion that resulted in flooding was conducted in the Juwana River basin. The mapping process involved all relevant stakeholders, starting from village officials, village disaster volunteers, and sub-district officials to local government agencies, such as the Pati Regency Regional Disaster Management Agency. Activities began by focusing on providing direction and education about understanding maps, understanding environment-based adaptation, and identifying disaster risk areas through maps. The next stage involves identifying the factors causing the flood disaster in Pati Regency and gathering input related to desired planning from the community, especially concerning solutions for flood problems and land conversion.

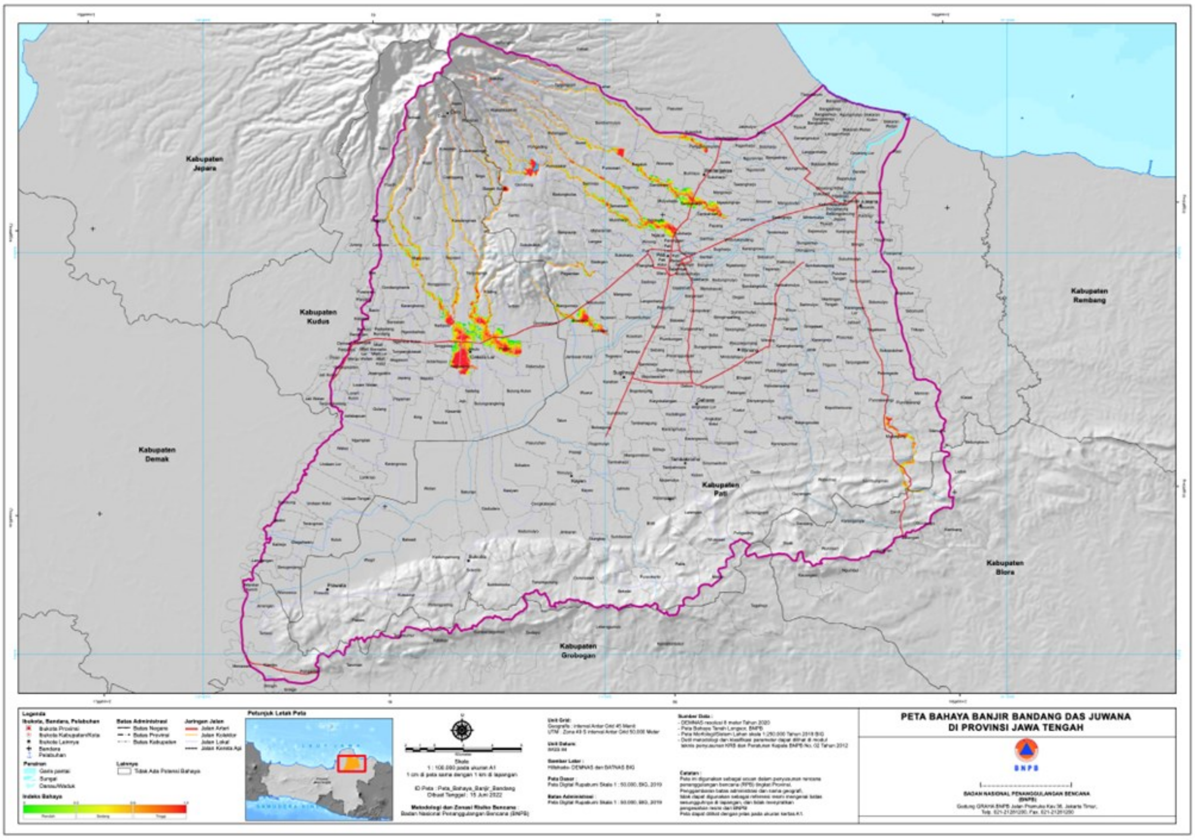

Figure 4.
Level of Flash Flood Hazard

From this process, maps of flood-prone areas were obtained, along with locations indicating changes in land use and cover and the factors causing flooding. One common occurrence is the conversion of land from perennial crops to seasonal crops, such as cassava for tapioca flour. The next stage involves planning carried out by stakeholders in flood disaster management downstream of the river. The community's response in the upstream area of the river, based on the discussions, was to continue preserving plants and forests by cultivating perennial crops like coffee and pine. Mitigation in the central part of the watershed is carried out by planting bamboo along the riverbanks to reduce erosion. Meanwhile, in the lower reaches of the river, BPBD Pati Regency recommends the concept of planting vetiver grass, which has strong roots, as part of a program to be implemented.

Figure 5.
Participation Process in Identification Mapping

Figure 6.
Flood Disaster Conditions in the Lower Juwana River (June 2022)

Adaptation Based on Environment

The understanding and implementation of environment-based adaptation in participatory discussion activities, carried out by all stakeholders in affected areas, have not been fully achieved. To truly grasp the concept of EbA for disaster management, several aspects must be defined: Nature-based solutions, community participation, resilience and adaptability, and multiple benefits.

The first aspect is the utilization of natural resources by integrating natural processes and ecosystem services into strategies for disaster risk reduction and climate change adaptation. For example, restoring or conserving wetlands and mangroves can help protect areas from flooding. In some locations, especially in the upstream areas, environmental conditions have been considered and are supported by regional policies related to protected areas. However, in the central part of the watershed, cassava is planted to boost the local economy, but this impacts the downstream area where sedimentation from open land occurs.

The aspect of community participation related to disaster management plans emphasizes the active involvement of local communities in the decision-making process. Community knowledge and traditional practices often provide valuable insights into ecosystem management and disaster risk reduction that are not yet fully established. A problem within the EbA concept, particularly regarding upstream and downstream management, is "sectoral ego," meaning each region prioritizes its own interests. Aspects of resilience and adaptation aim to increase the resilience and adaptability of ecosystems and communities. By protecting and restoring natural habitats, ecosystems are better equipped to absorb and recover from disturbances caused by disasters or climate change. Currently, community efforts in Pati Regency are only observed in a few places, such as the lower reaches of the Juwana River, where the community has started to build and rehabilitate the river from siltation, which often results in flooding. Regarding the aspect of multiple benefits, which involves providing many additional advantages, including better livelihoods, improved biodiversity, and ecosystem services that support human welfare, the community has not yet fully realized these benefits.

CONCLUSION AND ACKNOWLEDGMENTS

Conclusion

This research successfully identified the role of community participation in flood disaster management in Pati Regency, Central Java Province, Indonesia. It applied community participation-based disaster management with analytical tools for land cover and land use changes to map the sources of flood disasters. Land-use change, driven by urbanization, agricultural expansion, and infrastructure development, has significant implications for ecosystems and their ability to provide essential services to people.. Another finding is that the application of Ecosystem-based Adaptation (EbA) has not been fully implemented in Pati Regency, which served as the research locus. The core issue identified is the "sectoral ego" among various regions within the upstream-downstream watershed area, which ironically becomes a source of disaster for the areas involved. This condition demands immediate resolution through cross-sectoral and inter-regional coordination, facilitated by local government.

This study offers valuable insights for regional and provincial development. First, for the Pati district government, it highlights the necessity of studying and enforcing spatial planning and land use regulations within the watershed. Second, for the Provincial Government of Central Java, inter-regional coordination is crucial because a watershed encompasses multiple administrative areas, not just one.

Acknowledgments

We extend our gratitude to the Pati Regency Government, especially BPBD, for providing data and facilitating the FGDs. We also thank Mr. Anang Wahyu Sejati, as Chair of CEGAS Diponegoro University, for supervising the Disaster Management Plan activities in Pati Regency.

REFERENCES

Abhas, K. J., Bloch, R., & Lamond, J. (2010). Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. World Bank Publications. https://openknowledge.worldbank.org/handle/10986/2241

Allen, K. M. (2006). Community-based disaster preparedness and climate adaptation: Local capacity-building in the Philippines. *Disasters*, *30*(1), 81–101. https://doi.org/10.1111/j.1467 - 9523.2006.00308.x

BPDAS Pemali Jratun. (2022a). *Monitoring dan Evaluasi Kinerja DAS Juwana*.

BPDAS Pemali Jratun. (2022b). *Monitoring dan Evaluasi Kinerja DAS Juwana*.

Buchori, I., Sugiri, A., Mussadun, M., Wadley, D., Liu, Y., Pramitasari, A., & Pamungkas, I. T. D. (2018). A predictive model to assess spatial planning in addressing hydro- meteorological hazards: A case study of Semarang City, Indonesia. *International Journal of Disaster Risk Reduction*, *27* (April), 415–426. https://doi.org/10.1016/j.ijdrr.2017.11.0 03

Cahyono, E. D., Fairuzzana, S., Willianto, D., Pradesti, E., McNamara, N. P., Rowe, R. L., & van Noordwijk, M. (2020). Agroforestry Innovation through Planned Farmer Behavior: Trimming in Pine–Coffee Systems. *Land*, *9*(10), 363. https://doi.org/10.3390/land9100363

Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social vulnerability to environmental hazards. Social Science Quarterly, 84(2), 242–261. https://doi.org/10.1111/1540-6237.8402002

Dewa, D. D., Buchori, I., & Sejati, A. W. (2022). Assessing land use/land cover change diversity and its relation with urban dispersion using Shannon Entropy in the Semarang Metropolitan Region, Indonesia. *Geocarto International*, *37*(26), 11151–11172.

Dewan, A. M., Yamaguchi, Y., & Rahman, M. Z. (2012). Dynamics of land use/land cover changes and the analysis of landscape fragmentation in Dhaka Metropolitan, Bangladesh. GeoJournal, 77(3), 315–330.

Dias, L. C. P., Pimenta, F. M., Santos, A. B., Costa, M. H., & Ladle, R. J. (2016). Patterns of land use, Extensification, and intensification of Brazilian agriculture. *Global Change Biology*, *22*(8), 2887–2903. https://doi.org/10.1111/gcb.13314.

Donatti, C. I., Harvey, C. A., Hole, D., Panfil, S. N., & Schurman, H. (2020). Indicators to measure the climate change adaptation outcomes of ecosystem-based adaptation. *Climatic Change*, *158*(3–4), 413–433.

Feloni, E., Mousadis, I., & Baltas, E. (2020). Flood vulnerability assessment using a GIS- based multi-criteria approach—The case of Attica region. *Journal of Flood Risk Management*,*13*(S1),1–15.

Goodchild, M. F. (2006). GIS and disasters: Planning for catastrophe. Computers, Environment and Urban Systems, 30(3), 227–229. https://doi.org/10.1016/j.compenvurbsys.2006.01.001

Indonesia, B. H. U. B. (n.d.). *Pengertian Ecosystem based Adaptation Framework Pengarusutamaan EbA Best Practices EbA*.

Ismail, Y. (2019). *Pengelolaan Sampah Berbasis Masyarakat*. *1*(1), 50–63.

Jongman, B. (2018). Effective adaptation to rising flood risk. *Nature Communications*, *9*(1), 9–11. https://doi.org/10.1038/s41467-018- 04396-1

Lambin, E. F., Geist, H. J., & Lepers, E. (2003). Dynamics of Land-use and land-cover change in tropical regions. *Annual Review of Environment and Resources*, *28*(1), 205–241.https://doi.org/10.1146/annurev.energy. 28.050302.105459

Luthfiah, A., Mukson, & Setiadi, A. (2017). Economic Efficiency Analysis Of The Use Of Production Factors On Cassava Farming In District Tlogowungu Pati Regency. *AGRISOCIONOMICS Jurnal Sosial Ekonomi Pertanian*, *1*(2), 146–154.

Nalau, J., Becken, S., & Mackey, B. (2018a). Ecosystem-based Adaptation: A review of the constraints. *Environmental Science and Policy*, *89*(August), 357–364.

Nalau, J., Becken, S., Schliephack, J., Parsons, M., Brown, C., & Mackey, B. (2018). The role of indigenous and traditional knowledge in ecosystem-based adaptation: A review of the literature and case studies from the Pacific Islands. *Weather, Climate, and Society*, *10*(4), 851–865.

Newport, J. K., & Jawahar, G. G. P. (2001). Community participation and public awareness in disaster mitigation. *Disaster Prevention and Management*, *12*(1), 33–36. https://doi.org/10.1108/096535603104 63838

Niu, J., Chen, Y., & Li, X. (2020). Integrated flood risk assessment and zoning using spatial multi-criteria decision analysis (MCDA) techniques in GIS. International Journal of Disaster Risk Reduction, 46, 101503. https://doi.org/10.1016/j.ijdrr.2020.101503

Ntajal, J., Lamptey, B. L., Mahamadou, I. B., & Nyarko, B. K. (2017). Flood disaster risk mapping in the Lower Mono River Basin in Togo, West Africa. *International Journal of Disaster Risk Reduction*, *23*, 93–103. https://doi.org/10.1016/j.ijdrr.2017.03.0 15

Rimba, A. B., Setiawan, B., Indratmoko, R., & Aoki, Y. (2017). Physical assessment of changes in land use and flooding in the Upper Ciliwung River Basin. Sustainable Cities and Society, 34, 16–27. https://doi.org/10.1016/j.scs.2017.06.013

Sassolas-Serrayet, T., Cattin, R., & Ferry, M. (2018). The shape of watersheds. *Nature Communications*, *9*(1), 1–8. https://doi.org/10.1038/s41467-018- 06210-4

Sultana, R., Irfanullah, H. M., Selim, S. A., & Budrudzaman, M. (2023). Vulnerability and ecosystem-based adaptation in the farming communities of droughtprone Northwest Bangladesh. *Environmental Challenges*, *11*(February), 100707. https://doi.org/10.1016/j.envc.2023.100 707

Tran, P., Shaw, R., Chantry, G., & Norton, J. (2009). GIS and local knowledge in disaster management: A case study of flood risk mapping in Viet Nam. *Disasters*, *33*(1), 152–169. https://doi.org/10.1111/j.1467- 7717.2008.01067.x

Twisa, S., & Buchroithner, M. F. (2019). Land-use and land-cover (LULC) change detection in Wami river basin, Tanzania. *Land*, *8*(9). https://doi.org/10.3390/land8090136

Wahyuni, S., Tanjung, H. B., & Oktavia, Y. (2020). The Empowerment Potentials Of Coffee Farmers By Agroindustry Practitioners Of Coffee Perfume In Kerinci Regency. *JERAMI Indonesian Journal of Crop Science*, *2*(2),86–91. https://doi.org/10.25077/jijcs.2.2.86- 91.2020

White, I., Kingston, R., & Barker, A. (2010). Participatory geographic information systems and public engagement within flood risk management. *Journal of Flood RiskManagement*, *3*(4), 337–346. https://doi.org/10.1111/j.1753- 318X.2010.01083.x

Winsemius, H. C., Aerts, J. C. J. H., Van Beek, L. P. H., Bierkens, M. F. P., Bouwman, A., Jongman, B., Kwadijk, J. C. J., Ligtvoet, W., Lucas, P. L., Van Vuuren, D. P., & Ward, P. J. (2016). Global drivers of future river flood risk. *Nature Climate Change*, *6*(4), 381–385.