

RISK-BASED INTEGRATION OF FAULT MITIGATION INTO SPATIAL PLANNING: LAND DYNAMICS AND SETTLEMENT VULNERABILITY IN TANAH DATAR

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ABSTRACT: Tanah Datar Regency is highly vulnerable to earthquake hazards due to the Semangko fault and its two active segments, Sumani and Sianok, which induce significant tectonic deformation and directly affect settlements and land-use dynamics. This study was conducted to fill the knowledge gap related to the integration of disaster mitigation in spatial planning, with two main objectives: 1) identifying and analyzing spatial conflicts that arise between the dynamics of land use change, the distribution of vulnerable settlements, and active fault disaster prone zones with the regional spatial planning of Tanah Datar Regency; and 2) formulating a model for integrating fault disaster mitigation into spatial planning based on risk analysis as a recommendation for sustainable spatial planning policies. The approach used is a mixed method with sequential explanatory variables. Quantitative analysis was conducted through spatial mapping to assess hazard levels, physical vulnerability, and the dynamics of land-use change, while qualitative analysis was used to validate the model and policy through regulatory interpretation and stakeholder interviews. The results show that 7.59% of Tanah Datar is in a high earthquake-hazard zone, followed by moderate (15.9%) and low (1.45%) hazards. Population distribution also shows that the majority of the population (20,094) lives in areas with a high level of impact, while 58,230 people are in the medium category and 67,87 people in the low category. This finding confirms the mismatch between settlement Development, land conversion dynamics, and the risk zoning applicable in the spatial plans. Therefore, the integration of disaster mitigation can no longer be positioned as an additional compent, but must become the primary foundation in spatial planning. This study recommends an integration model that places disaster risk maps as the primary reference in the formulation of spatial policies, thereby guiding the establishment of protected zones, settlements, and economic centers more safely and sustainably. This guide is expected to strengthen regional resilience and provide a scientific basis for the Development of evidence-based spatial planning policies.

Keywords: Disaster Mitigation, Active Faults, Earthquakes, and Spatial Plans

1. INTRODUCTION

Indonesia, based on its geotectonic layout, is a meeting place for four active plates in the world, namely; the Eurasian Plate, which has a very slow movement towards the southeast at a speed of around 0.4 cm/year, then the Indo-Australian Ocean Plate moves towards the north at a speed of 6.8-7.5 cm/year, for the Pacific Ocean Plate which moves towards the west at a speed of 12 cm/year. Finally, the Philippine Sea Plate begins to move northwestward [1].

The confluence of these four plates makes Indonesia one of the most unique places, and, of course, this plate confluence has both positive and negative impacts. One positive impact is the formation of unique geological structures in

Indonesia. The negative impact is that Indonesia is prone to geological disasters, including earthquakes, tsunamis, volcanic eruptions, landslides, sedimentation, and other destructive geological phenomena.

Another consequence is the formation of active faults that span nearly the entire Indonesian archipelago. [2] Geographically, the island of Sumatra lies within a highly active tectonic zone and hosts a series of active volcanic mountains extending from northern Sumatra to the Sunda Strait. Sumatra is cut by the active Sumatran fault (Semangko Fault). Areas along this fault are highly vulnerable to disasters, particularly earthquakes, as exemplified by those in West Sumatra [3].

The West Sumatra region is located within three active seismic zones: the Subduction zone (Meganthrust), the Mentawai Fault (*Mentawai Fault*), and the Semangko Fault. The areas traversed by this route are highly seismically active. Based on tectonic activity, particularly in Tanah Datar Regency, West Sumatra, which is located directly on the Sumatran fault zone, or the Semangko Fault, which is still active and experiences movement of 7 cm per year [4]. This will indirectly impact Development and other infrastructure.

The Sianok and Sumani segments pass through Tanah Datar Regency, West Sumatra, and are active, exhibiting significant changes. These segments represent a small portion of the fault. [2]. Historically, a destructive earthquake measuring 6.4 on the Richter scale occurred in Tanah Datar Regency in 2007, resulting in numerous fatalities. [5]. This segment is designated as a disaster-prone zone.

The pressure of rapid population growth has led to massive landscape transformation in Tanah Datar Regency. According to Statistics Indonesia (BPS) data, the population reached 383,230 in 2024, resulting in rapid residential Development. Rapid settlement will not be consistent with the Regional Spatial Plan (RTRW), which has been established as a regional regulation. Failure to comply with RTRW policies may result in land use that is not consistent with its intended function. [6-7]. What should have been a protected area has become residential and agricultural land, and so on.

Integrating disaster mitigation into spatial planning positions disaster risk as a central variable in spatial decision-making [8]. This perspective aligns with the principles of risk-sensitive land use planning, which emphasizes that all spatial Development activities must consider regional hazard levels, vulnerability, and capacity [9]. In the context of active fault hazards, such integration links geological analysis, land-use dynamics, and the distribution of vulnerable settlements to safer and more informed spatial arrangements [10]. GIS plays a strategic role in this process by enabling detailed spatial analyses that model the relationship between hazard sources and settlement exposure. Furthermore, risk assessment results generated through GIS provide a clear picture of potential losses if Development proceeds without considering mitigation measures

2. METHODS

The research approach used in this study is a mixed-methods design with a sequential explanatory [14]. Namely, in the first stage, the research is characteristic by data collection and quantitative data analysis (spatial analysis). Secondly, qualitative research is used to collect

[11].

Law No. 26 of 2007 concerning spatial planning explicitly states that spatial planning, particularly for residential areas, must consider and avoid disaster-prone areas. Spatial planning can be divided into three categories: optimising resource utilisation, resource distribution, and sustainability [6].

The conversion of many areas to residential and other uses is a common phenomenon, often without consideration of disaster risk or other factors, leaving them vulnerable to disasters. This phenomenon is of particular concern and can increase the potential for loss of life and material damage during earthquakes or other disaster [12]. The interaction between geological hazards, such as earthquakes, and socioeconomic vulnerability (the concentration of settlements in Tanah Datar Regency) increases the risk of disaster impacts. Therefore, a spatial approach to mapping settlement vulnerability, coupled with an analysis of land-use change dynamics, is crucial. One crucial element in reducing the risk of geological disasters is educating the public about the potential for landslides and earthquakes at specific locations [13].

Regional vulnerability to earthquakes can be assessed using an information system to characterize the spatial distribution of disaster-prone areas. The Tanah Datar district is selected as a case study because it is traversed by two active segments, with relatively rapid residential Development and land-use conversion. Tanah Datar district is a vital cultural and agricultural area in West Sumatra, with potential for disasters and the capacity of its people, as shown in the community's socioeconomic conditions, which are the main determinants of an area's vulnerability. The presence of a population, as indicated by Development, is also a factor to consider when determining an area's vulnerability [13].

This mapping not only illustrates the distribution of vulnerability but also analyzes land-use changes that could exacerbate or mitigate future disaster risk. This study aims to fill a knowledge gap by integrating physical vulnerability analysis of settlements with the temporal dynamics of land-use change along active fault segments. It is hoped that this will provide a scientific basis for evidence-based spatial planning and disaster.

data and conduct data analysis regarding (policy and model validation as an explanatory and

applicable research design), to strengthen the results of the quantitative research conducted in the first stage. The tools used in this research include hardware and software. The hardware used includes laptops and other equipment.

ArcGIS software is used to support data processing and analysis. In addition to ArcGIS, Microsoft

3. RESULTS AND DISCUSSION

3.1 Identification and Analysis of Spatial

The growth of a region is inseparable from the changes that accompany it; not only economic issues and population growth, but also the region's dynamics of change affect land use in the Tanah Datar district. [15]. The following land-use changes occurred in the Tanah Datar district, as shown in Figure 1. The map interpretation indicates that the land-use change category is complex, encompassing vegetation, empty land, agricultural land, built-up land, and other categories. Based on the available spatial

Excel and Microsoft Word are also available to support data processing and research preparation.

information, it is clear that the Tanah Datar district has undergone significant land-use changes driven by both anthropogenic factors and natural ecological processes. Land conversion that occurs is not only in the form of a fixed category, but can change into a category of land conversion by involving a combination into other forms of land conversion, for example; vegetation land becomes agriculture, vacant land becomes shrubs, then shrubs become agricultural land, while agricultural land becomes settlements, and the final body changes into vegetation in several areas on riverbanks. Moreover, the Development of settlements and agricultural intensification are the main drivers of changes in land conversion.

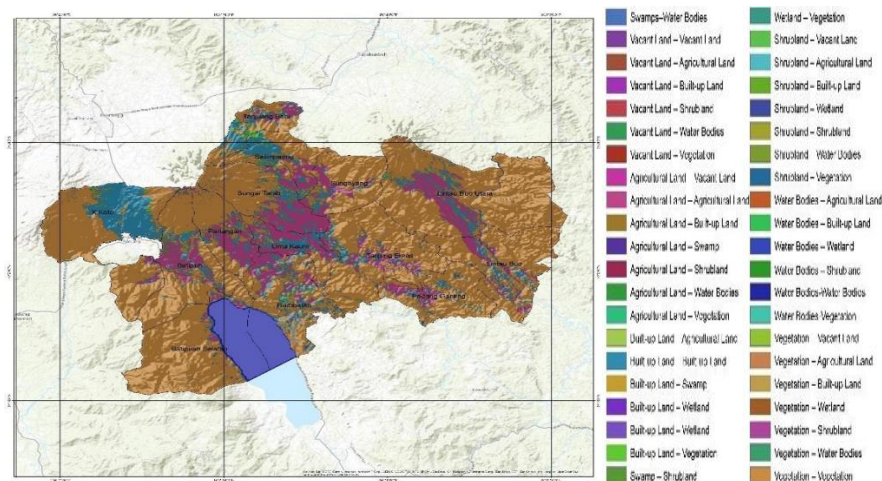


Fig 1. Land Use Change in Tanah Datar Regency

The image above shows the results of land conversion mapping conducted using overlay techniques. Overlay techniques are spatial analysis methods that combine two or more map layers to produce new information. [16]. The overlay results on the land conversion map for Tanah Datar Regency from 2005 to 2024 provide a comprehensive picture of land conversion dynamics in the regency. Overall, the findings on land-cover changes provide a basis for spatial planning for sustainable environmental management, particularly for maintaining a

balance between Development needs and land resources.

3.2 Mapping of Earthquake Hazard Zone Levels

The areas within the earthquake hazard zone were identified from data provided by ina-risk. The scoring analysis was also obtained from ina-risk, which assesses physical, environmental, social, and economic vulnerability, as documented in prior research. These results will be overlaid and then classified, as shown in Table 1, according to the level of earthquake-hazard vulnerability.

Table 1. Earthquake Hazard Zone Levels

No	Class	Area (Ha)	Percentage (%)
1.	Low	22660,43	16,45%
2	Currently	21988,21	15,96%
3.	High	93087,24	67,59%
	Total	137735.88	100.00%

Source: Secondary data, 2025

Based on Table 1, the Tanah Datar district is in a high-level or zone of earthquake hazard, covering approximately 93,087.24 Ha, or 67.59% of the district's total area, making it the area most affected by this hazard. Furthermore, for The area

with a moderate level of vulnerability covers approximately 21,988.21 hectares, or 15.9% of the total area of Tanah Datar Regency. Meanwhile, the lowest earthquake hazard zone covers approximately 22,660.43 hectares, or 16.45% of the total area of Tanah Datar Regency.

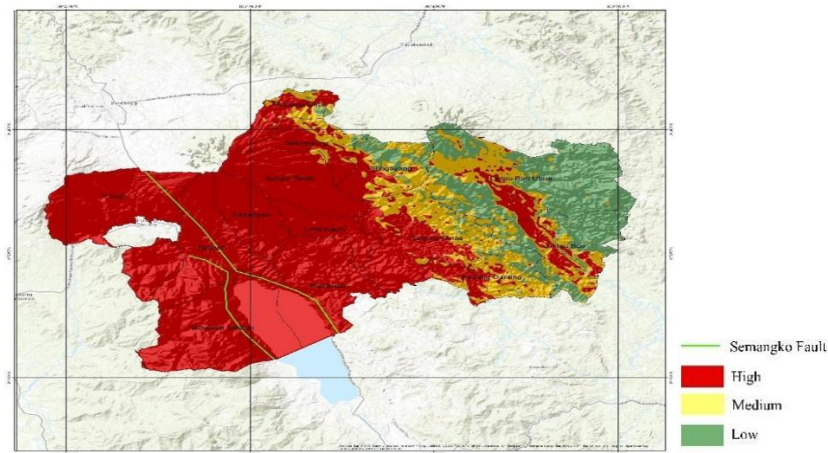


Fig 2. Earthquake Hazard Level Map

Mapping results show that most of Tanah Datar Regency falls within the high-risk zone, marked in red on the map. This zone is generally located near fault lines, and tremors intensify during tectonic activity. These areas include the districts of X Koto, Batipuah, South Batipuah, Rambatan, Pariangan, Lima Kaum, Sungai Tarab, and Tanjung Baru. The presence of faults that directly cross these areas makes them vulnerable to landslides, soil deformation, structural damage, and liquefaction.

Thus, the moderate hazard zone is marked in yellow on the map. This area is slightly farther from the fault line but has unstable geological characteristics, particularly in several areas with steep topography. This area also requires attention, particularly in spatial planning, to develop public infrastructure and housing. This area is quite steep and at risk of damage during earthquakes. It also requires attention, especially in spatial planning, for the construction of public infrastructure and housing farther from the fault line. However, it exhibits unstable geologic characteristics, particularly in areas with steep topography. This area is at risk of damage during an earthquake. This area also requires attention, particularly in spatial planning, to develop public infrastructure and housing. On the other hand, the low-level hazard zone, marked in green, has stable geology and is located quite far from active fault lines. Therefore, this zone remains seismically active, but the intensity is relatively low compared with

other areas. In this zone, the risk of damage can be minimised by implementing earthquake-resistant construction in accordance with national standards.

Overall, this map provides information on earthquake hazard zones, which are crucial for spatial planning, disaster mitigation, and infrastructure Development in Tanah Datar Regency. Areas with high hazard potential, in particular, should be directed to avoid concentrated Development in a single area, especially given the large population and the need for robust construction. Public education on disaster preparedness is also needed to minimise potential future impacts [17].

3.3 Population Vulnerability to Earthquake Hazards

In the context of earthquake hazard impact, the population is the most vulnerable, as evidenced by the intensity of damage to built-up areas, which will undoubtedly cause loss of life and material losses. In addition to built-up areas, damage can occur in non-built-up areas, including vegetation, agricultural land, forests, and other natural habitats. The threat of earthquakes is persistent, particularly in Tanah Datar Regency, given the proximity of the Sumani and Sianok segments. The following spatial analysis will be presented in maps and tables, divided into three classes: low, medium, and high [18].

Table 2. Impact of Settlements on Earthquake Hazards in Tanah Datar Regency

No	Class	Subdistrict	Percentage (of souls)
1.	High	Batipuah Selatan, Rambatan, Batipuh, X Koto, Pariangan, Lima Kaum, Sungai Tarab, Tanjung Baru	260.094
2	Currently	Padang Ganting, Tanjung Emas, Sungayang, Salimpaung	58.230
3.	Low	Lintau Buo, Lintau Buo Utara	67.876

Source: Secondary data, 2025

The Table above presents information on the classification of variable levels measured by demographic and social conditions, with specific categories, as well as on population density and vulnerability levels. This data was obtained from ESRI and then analysed spatially. It is estimated that approximately 260,094 people in Tanah Datar Regency live in areas with high earthquake risk.

Meanwhile, in areas with a moderate population density, the percentage is 58,230. In areas with a low population density, the percentage is 67,876. For more details, a map showing the distribution of residential areas affected by earthquake hazards in Tanah Datar Regency is provided.

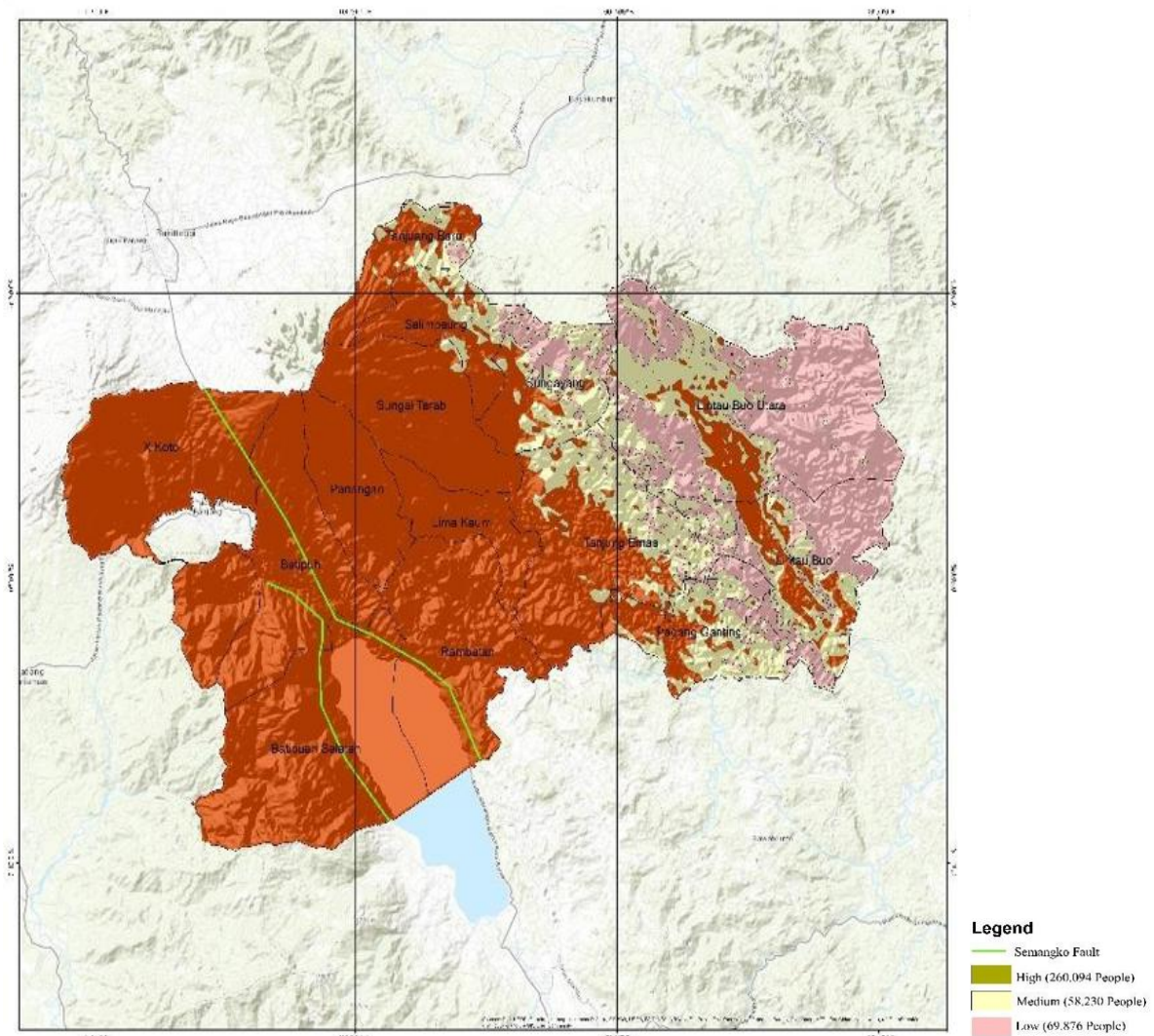


Fig 3. Earthquake Risk for the Population of Tanah Datar Regency

The map above shows earthquake hazards to settlements and the population of Tanah Datar Regency, depicting the level of vulnerability of communities living near the Semangko fault (Segments: Sumani and Sianok) and the distribution of settlements in this area. This mapping is important because this region lies within an active seismic zone with a history of high tectonic activity. The map shows that the impact on the population is divided into three classes: low, medium, and high.

In the high-impact class, marked with a green map, this area has the largest impacted population, around 260,094 people. Therefore, it is a vulnerable area, because this area is an area traversed by two active segments: the Sumani and Sianok Segments, which are indirectly adjacent to zones prone to earthquakes or various other tectonic activities. Furthermore, the large population in this area has led to population concentration, with various centres of economic activity and other infrastructure. Therefore, it has a reasonably high risk of material damage and loss of life in the event of a disaster.

Furthermore, in the area with a moderate level of exposure, shown in the yellow map with a population of approximately 58,230 people, this means that the potential impact in this area is in the moderate category; when a disaster or other tectonic activity occurs, the risk of material damage is not as significant as in the high zone. The area in this region is generally adjacent to hilly slopes, specifically the transition zone between the high and low zones.

Meanwhile, in the low-exposure class, this area is marked in pink on the map and has a population of approximately 69,876. These sub-districts are located relatively low because they are far from active fault lines and have gentle, stable topography. Residents living in these areas are at lower risk, even if earthquakes or other tectonic activity occur.

3.4 Disaster Mitigation Integration Model into Tanah Datar Regency's Spatial Plans

Tanah Datar Regency is a regency in West Sumatra. Geographically, this area is traversed by mountains that form part of the Barisan Mountains and is surrounded by extensive rice fields [19]. With its diverse landscape, this region is prone to several hazards, including earthquakes (due to its location along the Sumani and Sianok Fault Lines or Segments), landslides, floods, and eruptions of Mount Marapi. Anthropogenic factors, including land conversion, population growth, and Development activities in disaster-prone areas,

further exacerbate this disaster vulnerability.

Thus, the conventional Development method that ignores disaster considerations is no longer relevant; it is necessary to integrate Development with a comprehensive disaster mitigation concept into the Regional Spatial Plan (RTRW), which is essential for strategic reasons. The integration of adaptive and community-based disaster mitigation is important. Especially in Tanah Datar Regency, because it can support disaster-resilient spatial planning, thereby significantly enhancing regional resilience to various disasters [20].

If a region fails to integrate disaster-mitigation-based Development with comprehensive spatial planning (RTRW), the RTRW document could become static or unresponsive to the dynamics of potential risks [21]. This could reduce the effectiveness of spatial planning and, conversely, trigger new disasters or exacerbate existing ones.

Tanah Datar Regency will face a heightened sense of urgency if it adopts a disaster-mitigation-based Development concept and spatial planning to ensure safety and protect the entire community, particularly residents in disaster-prone areas [22]. This is a strategic step to ensure sustainable Development and public investment, assuring the potential risks posed by geological and hydrometeorological hazards.

Moreover, if this integration is implemented correctly, it can help minimum long-term economic losses arising from spatial planning that fails to consider future risks. In line with several national regulations, each region is free to organize its own spatial planning at the provincial, district/city, or village level. In accordance with Law No. 32 of 2004, Article 14, paragraph 2, grants the government authority to implement spatial planning. Furthermore, Law No. 26 of 2007 concerning spatial planning and Law No. 24 of 2007 concerning disaster management explicitly state the importance of minimum disasters in the preparation of regional spatial plans. [23].

In creating an ideal model for integrating disaster mitigation-based Development and spatial planning, it must be holistic, participatory, and in accordance with established regulations. In the initial stages, after producing several maps, this map can describe the situation in Tanah Datar Regency, particularly with respect to threat elements, vulnerabilities, and capacities, and explain these for each type of disaster. By

utilising the map of land-cover change, the map of earthquake hazard levels from highest to lowest, and the map of the vulnerability or impact of disaster hazards on the population. Given the completeness of this mapping data, it can serve as a basic source of information for decision-making in disaster-mitigation-based spatial planning [24].

The next step is to align the disaster risk map with the spatial planning and utilisation of areas, thus establishing a spatial planning structure (*RTRW*), for example, designating areas with a high risk of disaster as protected areas, and recommending areas with a low risk of disaster as residential areas or economic centres. This will enhance safety for both the environment and the community.

In developing relevant planning strategies by synchronization planning documents (RPJMD, *RTRW*, KRBD), collaborating to utilise a geospatial information system based on potential disaster hazard risks, and involving the community in Development planning [25]. The implementation of integration, limited to document preparation, must also be accompanied by effective Development control to ensure that building permits or IMBs approve Development in accordance with zoning provisions based on disaster hazard risk maps [25].

It also requires an integrated regional government team, with collaboration among agencies such as the PUPR Department, BPBD, BAPPEDA, and the Environmental Agency, to ensure that Development considerations align with disaster mitigation measures and comply with the applicable *RTRW* [25]. Regional governments will be considered successful if they can integrate risk into Development to build stronger social and economic resilience in the event of disasters or other crises.

4. CONCLUSION

Based on the research results, it can be concluded that Tanah Datar Regency is highly vulnerable to earthquake disasters. This is because the area is traversed by the Semangko Fault, which comprises two active segments, namely the Sumani and Sianok Segments, and can cause earthquakes. Most of the Tanah Datar Regency area is in a high earthquake-hazard zone (67.59%), followed by moderate (15.9%) and low (16.45%) hazard. This study also identified areas with population-level impacts on potential earthquake hazards, measured by population distribution; most of the population has a high impact, with 260,094 people. The population is in the moderate range, at 58,230. Moreover, the population in the lowest

area is approximately 67,876. Integrating disaster mitigation into the Development of the Tanah Datar Regency Spatial Plan (*RTRW*) is not merely an option but a necessity for achieving sustainable Development. The recommended integration model uses disaster risk maps as the primary reference for developing spatial planning policies. These maps can then be used to define zoning areas, such.

5. REFERENCES

- [1] M. Sarkowi, R. C. Wibowo, And I. B. S. Yogi, "Potensi Gempabumi Di Sepanjang Sesar Semangko Segmen Lampung," Vol. 03, No. 01.
- [2] A. Kurniawan Et Al., "Analisis Seismisitas Dan Mekanisme Fokus Sesar Sumatera: Studi Kasus Segmen Semangko Dan Selat Sunda," J. Teknol. Dan Inov. Ind. Jtii, Vol. 5, No. 2, Oct. 2024, Doi: 10.23960/Jtii.V5i2.98.
- [3] S. Erfani And I. R. Sari, "Analisis Model Struktur Bawah Permukaan Berdasarkan Tomografi Seismik Wilayah Sumatera Barat Menggunakan Lotos12," Wahana Fis., Vol. 6, No. 1, Pp. 59–70, June 2021, Doi: 10.17509/Wafi.V6i1.34036.
- [4] O. Niroha, A. Putra, And A. F. Pohan, "Pemodelan Struktur Bawah Permukaan Menggunakan Metode Seismik Refraksi Pada Prospek Panas Bumi Nagari Aie Angek, Kabupaten Tanah Datar," J. Fis. Unand, Vol. 10, No. 4, Pp. 525–531, Nov. 2021, Doi: 10.25077/Jfu.10.4.52
- [5] P. N. Sari, "Identifikasi Kesiapsiagaan Masyarakat Terhadap Bencana Gempa Bumi Di Segmen Sianok Pada Zona Patahan Semangko (The Sumatran Fault Zone) Kabupaten Agam," Vol. 3, No. 2. "[No Title Found]," J. Nat. Resour. Environ. Manag
- [6] Y. Dewi And D. Chandra, "Analisis Perkembangan Dan Kesesuaian Lahan Permukiman Terhadap Rtrw Kota Padang Panjang," Vol. 10, 2025.
- [7] W. Winarti, T. F. Fathani, And D. Legono, "Disaster Risk Analysis To Support The Development Of Regional Spatial Plan Of Tasikmalaya Regency, Indonesia," J. Civ. Eng. Forum, Vol. 4, No. 2, P. 167, May 2018
- [8] S. Wahyu Et Al., "Flood Hazard Risk

- Assessment Based On Multi-Criteria Spatial Analysis Gis As Input For Spatial Planning Policies In Tegal Regency, Indonesia,” *Geogr. Pannonica*, Vol. 27, No. 1, Pp. 50–68 “Isprs-Archives-Xlviii-5-W3-2025-137-2025.”
- [9] R. Singh, “The Role Of Geographic Information Systems (Gis) In Disaster Management And Planning,” *Int. J. Geogr. Geol. Environ.*, Vol. 6, No. 2, Pp. 195–205, July 2024, Doi: 10.22271/27067483.2024.V6.I2c.
- [10] A. Gunawan And P. Khadiyanto, “Kajian Aspek Bentuk Lahan Dan Geologi Berdasarkan Mikrotremor Dalam Perencanaan Ruang Kawasan Rawan Gempa Di Kabupaten Bantul Daerah Istimewa Yogyakarta (Studi Kasus: Kecamatan Bantul, Jetis, Imogiri, Dan Kretek),” *J. Pembang. Wil. Kota*, Vol. 8, No. 2, P. 178, June 2012, Doi: 10.14710/Pwk.V8i2.1157
- [11] E. A. Giofandi, B. A. R. Bunga, B. Barus, And W. Iskandar, “Community Vulnerability Assessment Against Landslide Hazard Potential In Tanah Datar Regency, Indonesia,” Vol. 03, No. 01, 2024.
- [12] N. Saputra, “Desain Penelitian Mixed Methodesain Penelitian Mixed Method”.
- [13] I. Dewata, “Dynamic Model Of Land Use Change In Landslide Hazard Zones In Tanah Datar District, West Sumatra,” Vol. 3, No. 1, 2019.
- [14] M. F. Yassar Et Al., “Penerapan Weighted Overlay Pada Pemetaan Tingkat Probabilitas Zona Rawan Longsor Di Kabupaten Sumedang, Jawa Barat,” *J. Geosains Dan Remote Sens.*, Vol. 1, No. 1, Pp. 1–10, May 2020, Doi: 10.23960/Jgrs.2020.
- [15] I. Sugiyarto, R. Irawan, And D. Rosiyadi, “Pengelompokan Dampak Gempa Bumi Dan Kerusakan Pada Wilayah Berpotensi Gempa Di Provinsi Sumatera Barat”.
- [16] F. Fauzan And N. Widya, “Pengaruh Topografi Terhadap Divergensi Fenotip Katak Fejervaria Canrivora Di Kabupaten Tanah Datar,” *Menara Ilmu*, Vol. 16, No. 1, Jan. 2022, Doi: 10.31869/Mi.V16i1.3108.
- Mamuju,” *Urban Reg. Stud. J.*, Vol. 7, No. 2, Pp. 190–203, June 2025, Doi: 10.35965/Ursj.V7i2.6043.
- [18] Maulana Jordan Al Fadhi, Billy Septrianda Putra, Reka Khorisma, Wulandari, And Edra Satmaidi, “Mitigasi Bencana Dalam Kebijakan Penataan Ruang Pasca Uu Cipta Kerja Dan Pp No. 21 Tahun 2021,” *J. Ilm. Kutei*, Vol. 24, No. 1, Pp. 56–68, July 2025, Doi: 10.33369/Jik.V24i1.42400.
- [19] M. R. Fairuzzen, V. H. Merpaung, A. A. Putra, A. A. Malik, And D. Mahipal, “Peran Tata Ruang Dalam Mitigasi Risiko Pembangunan Dan Pencegahan Bencana Alam”.
- [20] Y. Pramudika And I. P. Putra, “Kajian Kebijakan Tata Ruang Pasca Bencana: Studi Di Desa Tompe, Donggala, Sulawesi Tengah,” Vol. 23, 2024.
- [21] G. Tocchi, G. Cremen, C. Galasso, And M. Polese, “Integrating Multi-Hazard, Socio-Physical Information In A Holistic Index For Decision Making On Disaster Risk Reduction,” July 30, 2024, In Review. Doi: 10.21203/Rs.3.Rs-4660021/V1.
- [17] A. Y. Daud, S. Syafri, And B. Jaya, “Analisis Mitigasi Bencana Tanah Longsor Di Kecamatan Kalukku Kabupaten