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Characteristics of riverside residential areas: A case study in the Batang Arau Watershed, Padang, West Sumatra, Indonesia

Desy Aryanti[1]*, Sri Suryani[2], Yulianti[3], Afdal Nazmi[4]

[1]*Department of Architecture, Universitas Bung Hatta, Padang, INDONESIA*
[2]*Department of Architecture, Institut Teknologi Bandung, INDONESIA*
[3]*Settlement Infrastructure Center, Padang, INDONESIA*
[4]*Planning Consultant, Padang, INDONESIA*

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ABSTRACT

Riverside settlements play a crucial role in urban development, providing economic opportunities and social interactions while facing environmental challenges. This study examines the characteristics of riverside residential areas in two sub-districts (Berok Nipah and Koto Baru Nan XX) located in the Batang Arau Watershed, Padang, West Sumatra, Indonesia. Using a case study approach, the research analyzes settlement patterns, infrastructure conditions, socio-economic dynamics, and environmental impacts. Findings indicate that Berok Nipah exhibits a dense, linear settlement pattern with poor infrastructure, high flood risks, and inadequate sanitation, while Koto Baru Nan XX has a more irregular layout with better vegetation cover. The main challenges include unregulated waste disposal, poor drainage systems, and frequent flooding, which impact residents' quality of life. Despite these issues, strong community interactions and economic activities, such as trade and tourism, contribute to local resilience. To ensure the sustainability of riverside settlements in Batang Arau, integrated urban planning, improved infrastructure, and environmental conservation are essential. Strengthening disaster resilience and increasing community awareness will help balance urban growth with ecological preservation, fostering a more sustainable and livable riverfront environment.

[2*]Corresponding author. *E-mail address* : desyaryanti@bunghatta.ac.id
Co-authors. *E-mail address* : srisuryaniassociates@gmail.com, afdalnazmi@gmail.com

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1. INTRODUCTION

Riverine settlements thrive along riverbanks due to water access, fertile land, and transport routes, supporting agriculture, trade, and cultural development (Wantzen, 2023). Seasonal flooding enriches soil, aiding crop production (Quinton, J. N., & Fiener, 2024), while rivers foster major trade hubs (Bhonde, U., Choudhury, B., & Sachdeva, 2024). Fishing, tourism, and industry also drive urban riverfront economies (Simons, S., Kinjawadekar, A., & Kinjawadekar, 2024). However, these settlements face challenges like flooding, pollution, and informal expansion. Flood risks necessitate control measures, as seen in New Orleans (Mississippi) and Mumbai (Mithi) (Jha, A. K., Bloch, R., & Lamond, 2012). Rapid urbanization leads to informal settlements lacking sanitation, as in Jakarta (Ciliwung) and Dhaka (Buriganga) (Dangol, 2024). Industrial waste pollutes rivers, harming public health, as in Delhi (Yamuna) and Manila (Pasig) (May, 2006). To mitigate these issues, cities have undertaken riverfronts revitalization projects that balance economic growth and conservation, as seen in Singapore's Marina Bay and Seoul's Cheonggyecheon (Pattacini, 2021). Rivers also hold cultural and recreational value, hosting tourism and festivals, such as Bangkok's floating markets and Paris's river cruises (Un-Habitat., 2010). In conclusion, urban riverine settlements offer economic and social benefits but face flooding, pollution, and unregulated expansion. Sustainable management, urban planning, and climate resilience are essential for balancing development with environmental preservation.

1.1 Research Background

Batang Arau, located in Padang, West Sumatra, is a historically and economically significant riverine settlement. The river has long supported trade, transportation, and cultural activities, contributing to the local economy, particularly in tourism and waterfront businesses (Aryanti et al., 2024). However, rapid urbanization has led to major challenges, including pollution, flooding, and informal settlements. Industrial and domestic waste disposal have significantly polluted the river, threatening aquatic ecosystems and public health (Helard, D., Indah, S., & Ardon, 2019). Additionally, seasonal flooding and riverbank erosion pose risks to infrastructure and livelihoods, exacerbated by poor drainage systems and unregulated development (Aryanti et al., 2024). Efforts to revitalize Batang Arau focus on waste management, flood control, community engagement, and eco-tourism to balance economic growth with environmental sustainability (Aryanti et al., 2024). Implementing sustainable urban planning and conservation strategies is crucial for ensuring the resilience and future viability of Batang Arau as a thriving riverine settlement.

This study explores the challenges and opportunities in revitalizing Batang Arau as an urban riverine settlement. It addresses environmental issues, management strategies, and sustainable development while proposing policy recommendations. Despite its historical and economic value, pollution, flooding, and informal settlements endanger its sustainability. Therefore, integrating environmental conservation, urban planning, and community engagement is essential for its long-term resilience.

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Fig. 1. Batang Arau Watershed
Source: Author

2. LITERATURE REVIEW

Urban riverfronts play a key role in economic, cultural, and transportation activities (Kondolf, G. M., & Pinto, 2017). However, their development poses urban planning challenges, requiring a balance between growth and sustainability (Mersal, 2016). Successful projects must integrate economic progress with environmental conservation to ensure long-term viability (Roseland, 2000). Yet, issues such as flooding risks, environmental degradation (Rana, 2011) and displacement of low-income communities create obstacles (Li, 2016) Therefore, strategic and inclusive planning is essential to harmonize economic growth, sustainability, and social well-being (Simons et al., 2023).

Urban riverfronts support economic growth, social development, and sustainability but face risks from flooding, erosion, and climate change. Therefore, resilience requires disaster management, sustainable planning, and community adaptation (J. Ensora, 2009). Frequent storms and heavy rainfall cause property damage and displacement, worsened by rapid urbanization and poor drainage, as seen in Jakarta (Ciliwung River) and Mumbai (Mithi River) (Sudmeier-Rieux et al., 2016). Additionally, riverbank erosion threatens infrastructure, displacing communities in Bangladesh due to land loss (Kaiser, 2023). Moreover, the Penang state government has accelerated flood mitigation projects, including river deepening to manage excess rainwater (Saad et al., 2023). In Pahang, Malaysia, the main flood-related issue is disaster management (Mabahwi & Nakamura, 2024). Water pollution heightens health risks during disasters, as seen in Delhi (Yamuna River) and Manila (Pasig River), where waste contaminates rivers (Researchers & Hill, 2024). To enhance resilience, cities must integrate disaster risk reduction and climate adaptation. Green infrastructure, such as wetlands and floodplain restoration, acts as natural flood barriers, as seen in New Orleans (Mississippi River) (Hendrickson & Moe, 2007). Additionally, structural mitigation plays a crucial role, as demonstrated by cities such as Bangkok (Chao Phraya River) and Rotterdam (Maas River), which have implemented flood barriers and advanced drainage systems (Hillen, 2015).

Community-based preparedness is vital for disaster resilience, as seen in Dhaka (Buriganga River), where slum communities adopt flood adaptation measures like elevated housing and improved sanitation (Asian, 2020). Long-term resilience requires policy, technology, and inclusive planning, necessitating zoning

regulations, climate-resilient infrastructure, and ecosystem restoration (Corfee-Morlot et al., 2012). Additionally, international collaboration enhances adaptive capacity and reduces vulnerabilities (Filho et al., 2019). While urban riverfronts drive economic and social growth, they face disaster risks. Strengthening resilience through sustainable planning, flood control, and community engagement ensures riverfronts protect both people and the environment.

Riverine landscapes, located near rivers, feature floodplains, riverbanks, deltas, and wetlands, with water levels fluctuating due to seasonal rainfall, tides, and upstream management (Huang, 2022). Fertile alluvial soil supports agriculture and vegetation, though erosion and sediment deposition reshape land stability and settlements (Wang et al., 2023). These landscapes provide habitats for diverse species, with wetlands aiding in biodiversity, water filtration, and flood control (Gopal, 2009). However, pollution, deforestation, and climate change threaten ecosystems, disrupting ecological balance and endangering species (Chakraborty, S. K., & Chakraborty, 2021).

Historically, riverine landscapes have supported human settlements due to their access to water resources, fertile soil, and natural transportation routes. Many riverbanks host thriving agricultural communities, fisheries, and trade hubs (Vasanthakumar, 2017). Moreover, urban riverfronts have become economic and cultural centres, attracting tourism, commerce, and recreation (Hussein, 2006). However, rapid urbanization, unregulated development, and informal settlements often lead to pollution, encroachment, and increased disaster risks (Bikis, A., & Pandey, 2023). Riverine landscapes face numerous challenges, including flooding, erosion, pollution, and habitat destruction. To address these issues, sustainable management strategies such as riverbank restoration, eco-tourism, and flood control measures are essential (Vasanthakumar, 2017). Cities like Singapore (Marina Bay) and Seoul (Cheonggyecheon) have implemented successful riverfront revitalization projects that balance urban development with environmental conservation (Cho, I. S., & Križnik, 2016).

The Batang Arau River has played a pivotal role in Padang's development, serving as a hub for trade and cultural exchange (Erniwati et al., 2023). Before European contact, local communities used the river for commerce, establishing Padang as a growing port (Colombijn, 2005). The arrival of the Dutch East India Company (VOC) in 1666 transformed the area into a major trading hub (Landwehr, 2024). The river's strategic location attracted Chinese, Indian, and indigenous traders (Cooke, N., & Li, 2004). The Chinese community built multi-story structures along the riverbanks, enriching the area's economy and culture (Yuzhong et al., 2024). During the 18th and 19th centuries, warehouses, trading offices, and banks emerged along Jalan Batang Arau, reinforcing the river's commercial significance (Colombijn, 2004). The British briefly occupied the area in the mid-18th century before it returned to Dutch control until 1942 (Oostindie & Roitman, 2014). As Padang expanded northward along the coast, the Batang Arau River remained a crucial boundary, shaping the city's adaptation to trade and geographical constraints (Marsden, 1811).

Overall, the historiography of riverine settlements along the Batang Arau River illustrates a dynamic interplay of indigenous development, colonial intervention, and multicultural contributions, all cantered around the river's strategic importance to Padang's growth.

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3. METHODOLOGY

This study was conducted in two sub-districts (Berok Nipah and Koto Baru Nan XX) in Padang, Indonesia (Fig.1). The study area is located along the Batang Arau watershed. The coordinates are -0.964425, 100.353531 for Berok Nipah and -0.962302, 100.381123 for Koto Baru Nan XX. The Batang Arau watershed has been a trade and cultural hub in Padang since its use by Minangkabau traders prior to European arrival. The Dutch East India Company (VOC) established a trading post in 1666, making it a colonial commercial centre. The area attracted Chinese, Indian, and Arab traders, leaving a lasting architectural heritage. While urbanization has reshaped the landscape, revitalization efforts focus on preserving its history and promoting sustainable development.

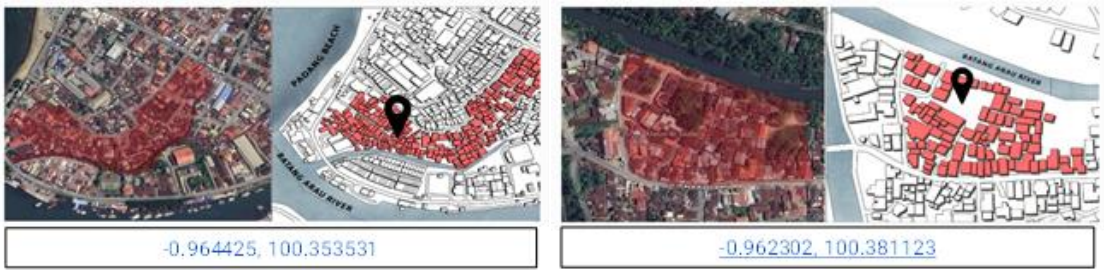

Fig. 1.Map of Study Area, the Location of Berok Nipah and Koto Baru Nan XX
Source: Author

This research employs a mixed-methods approach, integrating both qualitative and quantitative methods using primary and secondary data sources. Primary data collection includes field observations, questionnaires, and interviews, while secondary data was gathered through literature reviews. Observations assess infrastructure, with physical mapping visualizing spatial integration. Surveys were conducted with 100 households in Berok Nipah and 50 in Koto Baru Nan XX. Data collection was further supported by photographs, maps, and tables, with analysis focusing on factors shaping compact *kampung* settlements along the Batang Arau River.

4. RESULTS

The Batang Arau watershed features diverse settlement characteristics influenced by natural, human, and social factors, as well as housing and infrastructure. These factors shape residential patterns, with Berok Nipah following a homogeneous linear layout, while Koto Baru Nan XX has an irregular pattern.

Table 1. Comparison of Settlement Characteristics in Berok Nipah and Koto Baru Nan XX sub-district: A Case Study of the Batang Arau Watershed in Padang

Component	Berok Nipah Sub-district	Koto Baru Nan XX Sub-district
Nature	• The area lacks vegetation • It is located near the mouth of the river • Slum conditions are impacted by tidal and shipping floods. • Pollution caused by materials	• Vegetation grows within and along riverbank residences. • It is situated mid-river between upstream and downstream. • The level of slums in the area is influenced

	wreckage • Beach view strengthens the condition of the area	by waste from the research area • There is still space in the area
Man, and society	• Interaction is shaped by historical and beach tourism. • High urbanization results from the central location. • Public facilities are distributed throughout the area. • The area has a high population density.	• Interaction is influenced by people's daily activities • Urbanization is low in distant, low-lying areas. • Few public facilities spread around the area • It is low-density area
Residential and networking	• Most buildings are temporary with hitchhiked land status • Houses have hitchhiking status • Residential dwellings share a uniform design • Residential development is influenced by secondary arterial roads • The area is surrounded by neighborhood roads accessible from all boundaries. • Settlement expansion extends beyond the area.	• The area is dominated with semi-permanent buildings, most of which are constructed on rented land. • Houses have hitchhiking status • Buildings face irregular directions • Residential growth follows accessible neighbourhood roads. • Settlement expansion aligns with regional delineation.
Conclusion	Residential growth extends outward due to external activities and network access, creating a homogeneous pattern in Berok Nipah.	Limited access and housing density push development inward, expanding into vacant land and forming an irregular settlement pattern.

Source: Author

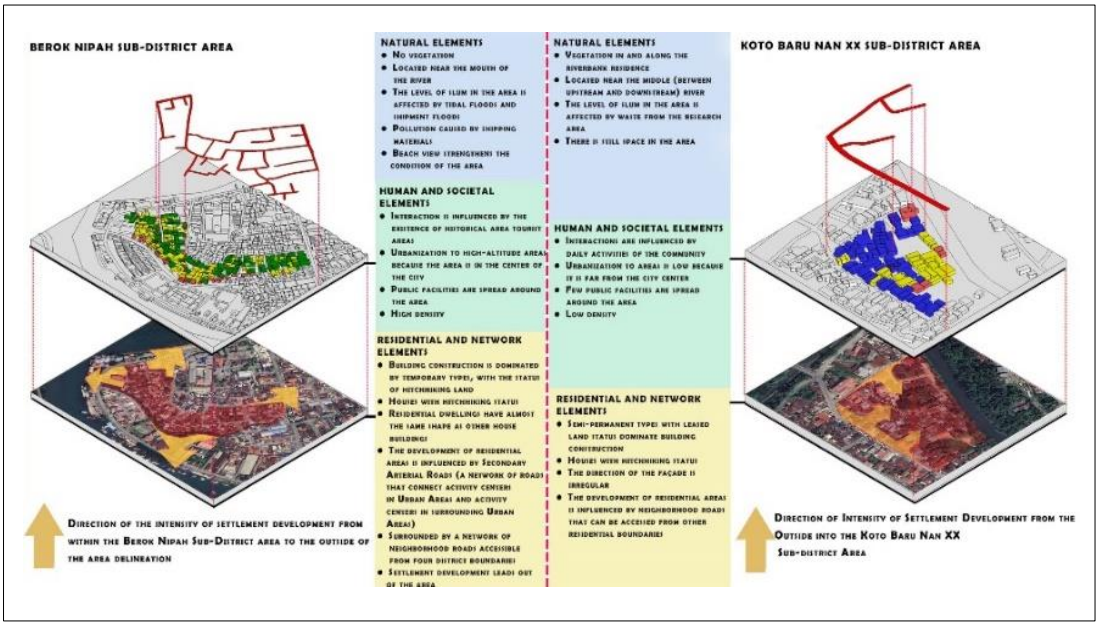

Fig. 2. Characteristics of Riverside Settlements in Batang Arau Area
Source: Author

5. DISCUSSION

5.1 Site Location

Watersheds, also known as catchment areas, are natural systems that collect and channel rainwater into rivers, lakes, or seas. The Batang Arau River, Padang's first settlement, holds historical significance. The city has two watersheds: Batang Arau, flowing through Berok Nipah and Koto Baru Nan XX, and Pisang River, passing through Bungus Barat and Teluk Kabung Selatan.

5.2 Population Data

According to SNI 03-1733-2004 on Housing Environmental Planning, the research area has a high density of 311 people/ha with 405 households. Flooding from the Batang Arau River led to the relocation of 244 households, but many returned due to their reliance on fishing. Consequently, Bantaran Kali Mati in Berok Nipah remains highly dense, while Koto Baru Nan XX is categorized as low-density. Data analysis applies Ekistics Theory, examining settlements through nature, society, housing, and networking. The result presented in Table 2 and Table 3.

Table 2. Population Density Level Based on SNI 03-1733-2004

Classification of region	Density			
	Low	Medium	High	Very Dense
Population Density	<150 people/ha	151-200 people/ha	200-400 people/ha	> 400 people/ha

Source: SNI 03-1733-2004, Procedures for Residential Environmental Planning

Table 3. Population Density in the Research Area

Sub-district	Area (Ha)	People	Head of Family	Density People/Ha
Berok Nipah	5,3	2020	405	381 (high)
Koto Baru Nan XX	2,09	276	69	138 (low)
Total	7,39	2,296	474	

Source: Author

5.3 Natural Elements

Padang has a high air temperature, ranging from 23°C–32°C during the day and 22°C–28°C at night, with humidity between 78%–81%. The study area, located in the Batang Arau watershed within Berok Nipah and Koto Baru Nan XX, covers 7.39 ha with a population of 2,296. It is also a cultural heritage area, influencing river activities and vegetation as shown.

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Fig. 3. Impact of Areas on Activities Along the River
Source: Author, 2024

As presented in Fig. 3, unlike Koto Baru Nan XX, which has abundant greenery, Berok Nipah lacks vegetation. Flooding in Koto Baru Nan XX leads to riverbank erosion and submerges homes and roads in Berok Nipah. Additionally, floods carry garbage and cause sewer overflows, worsening pollution. The absence of vegetation increases dampness and road flooding. Furthermore, the river is often misused for waste disposal, highlighting the urgent need for proper management to restore its ecological functions and ensure sustainability.

5.4 Human and Society

Riverbank settlements attract residents due to low rents (500,000–1 million IDR/month), but inadequate infrastructure, poor sanitation, and pollution discourage long-term living. Unregulated activities and low awareness worsen river sustainability, while poor roads and drainage lead to direct waste disposal. Despite these issues, social interactions foster strong community bonds, with daily gatherings at boat mooring stalls enhancing solidarity.

Table 4. Number of Population by Occupation

Occupation	Sub-district		∑	Percentage
	Berok Nipah	Koto Baru Nan XX		
Fisherman	14	5	19	15,32
Laborer	18	40	58	46,77
Cleaning Officer	3	-	3	2,42
Self employed	16	5	21	16,94
Driver	2	-	2	1,61
Civil Servants	6	4	10	8,06
Day traders	-	7	7	5,65
Scavenger	-	4	4	3,23
Total	59	65	124	100

Source: Author

Table 5. Number of Population by Income

Income	Sub-district		∑	Percentage
	Berok Nipah	Koto Baru Nan XX		
< from 200 thousand/month	2	-	-	-
200 – 500 thousand/month	14	10	24	19
500 – 1 million/month	20	5	25	20
1 -1.5 million/month	12	41	53	43
1.5 – 2 million/month	4	4	8	6

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> from 2 million/month	7	5	12	10
Total	59	65	124	100

Source: Author

5.3 Housing and Facilities

Community housing in the area consists of temporary, semi-permanent, and permanent types (Table 6). The settlement includes essential facilities such as schools, places of worship, and health centers. Narrow and unplanned alleys serve as important spaces for social interaction, with roads constructed from dirt, concrete, or wooden bridges. Open drainage channels direct wastewater into the river; however, these are often clogged by waste and tidal flooding, causing inundation. The settlement follow a linear pattern, shaped by river morphology, depth, and accessibility. Initially, houses faced the river for trade and transport, but the road construction shifted their orientation toward land. As the result, some homes turned sideways or backward, forming what is now known as riverbank housing.

Table 6. Characteristics of house buildings with permanent, semi-permanent and temporary types in the research area

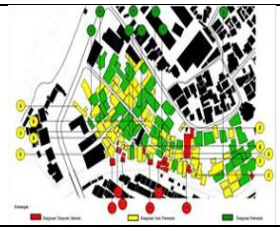
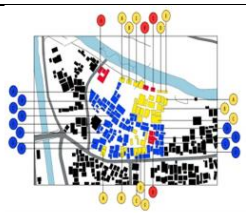
Description	Berok Nipah			Koto Baru Nan XX		
	Permanent	Semi-permanent	Temporary	Permanent	Semi-permanent	Temporary
Home conditions	Good	Good	Unlivable	Good	Good	Unlivable
Building construction	Concrete	Concrete and wood	Wood	Concrete	Concrete and wood	Wood
Orientation	Back to the river	Back to the river	Back to the river	Facing the road	Back to the river	Back to the river
Building floor	1 and 2	1	1	1 and 2	1	1
Ownership of bath, wash, toilet	Inside the house	Inside the house without septic tank	Not owning, hitchhiking	Inside the house	Inside the house	Inside the house
Livelihood	Employee. merchant	Freelance day laborers, cleaners	Fisherman, driver, scavenger, labourer	Merchant	Freelance day laborers, cleaners	Fisherman, driver, scavenger, labourer

Source: Author

Existing Conditions of Semi-Permanent Housing

Existing Conditions of Permanent Housing

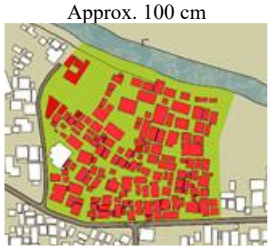


Existing Conditions of Temporary Housing	Map

Fig.4. Maps and Documentation of Building Types
Source: Author

Table 7. Settlement Patterns in the Study Area Based on the Network

Network Patterns	Sub-district	
	Berok Nipah	Koto Baru Nan XX
Road Network Dimensions	 Approx. 80 cm	 Approx. 100 cm
Road Network Pattern	 Characteristic homogeneous	 Unclear characteristics
Drainage	 Open	 Closed
Road network on the banks of the river		

Source: Author

6. CONCLUSION

Riverside settlements in the Batang Arau Watershed are shaped by a combination of environmental, socio-economic, and infrastructural factors. Berok Nipah exhibits a dense, linear pattern with poor infrastructure and high flood risks. In contrast, Koto Baru Nan XX has a more irregular layout with better vegetation. Common challenges across both areas include inadequate sanitation, poor drainage, and environmental degradation. Despite this, strong social interactions and economic activities contribute to community resilience. To ensure long-term sustainability, there is a pressing need for integrated riverfront management, infrastructure improvement, and enhanced disaster resilience strategies.

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8. CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

9. AUTHORS' CONTRIBUTIONS

All authors contributed to the writing of the article and have read and approved the final manuscript.

10. DECLARATION OF GENERATIVE AI IN THE WRITING PROCESS

AI tools (e.g, ChatGPT, Grammarly) were used for drafting, assistance, paraphrasing and grammar checking. All content was critically reviewed and edited by researchers' data availability/supplementary materials.

11. DATA AVAILABILITY/SUPPLEMENTARY MATERIALS

The datasets used and/or analysed during this study are available from the corresponding author upon reasonable request.

12. ETHICS STATEMENT

The authors declare that this research did not involve human or animal subjects.

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