Banda Bekali and local knowledge in flood management: 100 years of social and environmental interaction in Padang City

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Abstract. Floods have plagued Padang City for centuries, with severe events recorded almost annually between 1890 and the early 20th century, peaking in 1904. The damages during that period reportedly reached two million guilders. In response, the Dutch East Indies colonial government constructed the Banda Bekali canal system to mitigate flood risks. While the canal has reduced the severity of flooding, it remains a persistent issue in the city. This study, marking over 100 years since Banda Bekali's establishment, examines the canal's role in flood management. Using a qualitative-descriptive approach, the research focuses on the canal's sections in Padang, selecting informants through purposive sampling based on age, gender, and societal roles. Data collection includes observations, in-depth interviews, and literature reviews. The study aims to understand the community's interaction with the canal and the local knowledge surrounding flood control. It explores the Minangkabau people's flood and disaster management systems and reflects on the 100-year history of Banda Bekali as a mitigation strategy. Through triangulation, this research hopes to contribute to improved flood disaster management strategies in Padang, drawing on both historical analysis and contemporary local knowledge.

1 Introduction

Padang City, located in the province of West Sumatra, is an ancient city with a rich history. Throughout the 19th century, it was a thriving metropolitan area on Sumatra Island and served as the center of the Dutch East Indies government from May 20, 1784, until the period leading up to Indonesia's independence. The city's history began as a small fishing village along the banks of the Muara Batang Arau in the 14th century, primarily inhabited by the Rupit and Tirau people, who relied on fishing and trade for their livelihoods. Today, Padang City is recognized as a Rantau city of the Minangkabau ethnic group, with numerous historical artifacts and colonial architecture affirming its status as a central hub of governance and culture on Sumatra Island.

Flooding, a natural phenomenon exacerbated by human activities, has long been a pressing issue in Padang City. It results from a combination of factors: rainfall, river conditions, upstream conditions, regional topography, and tidal influences. Currently, the potential for flooding is heightened by damaged river bodies, deteriorated catchment areas, spatial planning violations, legal infractions, uncoordinated development planning, and low community discipline. Floods, a recurring natural disaster, almost inevitably occur during every rainy season. They are caused by various factors, including rainfall, watershed degradation, errors in river channel development planning, river siltation, and regional planning and infrastructure construction errors [1].

Padang City is particularly vulnerable due to its geographical conditions, which include hills and lowlands adjacent to the Indian Ocean. This makes it susceptible not only to floods but also to extreme weather events, coastal erosion, earthquakes, tsunamis, landslides, and other geological disasters. With five major rivers and sixteen smaller rivers, the city is frequently affected by floods, with several districts being especially prone to this natural disaster. Flash floods in the upstream areas cause significant damage, including riverbank erosion and destruction of agricultural and residential areas along the watersheds.

Padang City experiences high rainfall, with data from seven rain observation stations showing an average of 123 to 190 rainy days per year [2]. Annual rainfall ranges between 3,329 mm and 4,296 mm, with areas near the hills receiving more rainfall than coastal regions. This disparity leads to a higher risk of floods and landslides in elevated areas. The high rainfall intensity makes Padang City particularly prone to flooding, a persistent issue that has affected the city for hundreds of years.

To mitigate this, during the Dutch colonial era, the government recognized the flood problem and responded by constructing the Banda Bekali canal. Padang had already gained notoriety as a "flooded city," with significant flooding reported on December 5-6, 1898, March 25, 1904, and a major peak on September 28-29, 1907. The canal system, now known as Banda Bekali, was built to manage flooding in Padang by diverting the flow of the Batang Arau river, spanning 6.8 km in length and 20 meters in width, with an estuary near Purus Beach [1].

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Banda Bekali was designed to reduce flooding and support the city's drainage system, including small rivers, swamps, and sewers, which ultimately empty into the Indian Ocean. However, despite its construction over a century ago, floods in Padang City remain a recurring challenge. Nonetheless, the community's interaction with Banda Bekali has shaped a collective memory of floods, passed down orally through generations. This experience has fostered local knowledge systems that continue to inform community behaviors related to flood management.

The recurring floods have led to the development of distinct local knowledge systems within Padang's communities, particularly the Minangkabau people. This knowledge, rooted in the social, cultural, and environmental context, allows residents to interpret signs of impending floods, such as changes in river color, the appearance of debris, and fish behavior. Such knowledge is invaluable in disaster-prone areas, where community responses are often dictated by the ecological systems they inhabit.

As noted by Abdullah academic studies on disasters in Indonesia often perceive disasters as isolated events rather than integrated elements of collective knowledge and social policy [3]. However, local knowledge systems, passed down through generations, represent a significant resource for understanding and mitigating disaster risks. These systems, while not always explained in scientific terms, are crucial for effective flood management. Historical records reveal that Indonesia has faced numerous large-scale natural disasters, and the integration of local knowledge with formal disaster management strategies offers a path forward in creating more robust solutions [4].

This study explores the interplay between infrastructural interventions, such as Banda Bekali, and the traditional local knowledge systems developed by the residents of Padang, particularly the Minangkabau community, in addressing the recurrent flooding problem. The research aims to highlight how these complementary approaches engineering solutions and indigenous practices can be integrated to create more effective flood management strategies in Padang City.

2 Research methods

This research uses a qualitative-descriptive method to explore and understand flood management and local knowledge in Padang City, relying on observation and inductive analysis [5]. This approach provides a detailed view of human practices and knowledge, focusing on how the community responds to flooding [6]. The main focus of the study is the Banda Bekali canal and surrounding rivers that are frequently affected by floods.

The study took place in flood-prone areas along the Banda Bekali canal in Padang City. Informants were selected through purposive sampling to ensure a wide range of perspectives. Priority was given to individuals with direct experience of recurring floods, including those living in vulnerable areas. The sample included a diverse group of community members, such as local leaders, elderly residents with extensive flood experience, younger generations, and those whose livelihoods are closely tied to the rivers (fishermen, sand collectors). A balance of age and gender was also ensured to capture varied flood-related knowledge across different demographics. This method ensured that the study reflected a broad spectrum of community views and practices.

Data collection was carried out using three main methods: observation, in-depth interviews, and a literature review. The observations took place over three months, focusing on daily activities near the canal, such as fishing, farming, and sand collection, as well as local flood management practices. Researchers documented how residents prepared for floods, how they interpreted signs like water levels and debris, and their actions during flood events. The environmental condition of the river was also observed, with notes taken on water flow, sedimentation, and landscape changes.

Interviews were conducted with 16 selected informants to uncover local knowledge and beliefs about flood management. Questions explored their experiences with floods, how they predict floods, traditional practices used to prepare for them, and their thoughts on the effectiveness of Banda Bekali. These semi-structured interviews allowed for open discussion while guiding the conversation towards specific themes.

In addition, a thorough literature review was conducted to support the primary data. This included historical records of floods in Padang, studies on disaster response, and research on similar knowledge systems in other regions. The literature review helped contextualize the field findings and connect them with broader disaster management theories.

This research applies Cultural Ecology which explores how human societies adapt to their environments through culture [7]. This framework helps explain how the Minangkabau community in Padang has developed flood management practices over time in response to recurring floods. Their strategies, such as using natural signs to predict flooding or modifying their use of river resources, are examples of adaptive responses to environmental challenges. Steward's theory of multilinear evolution shows that these practices are specific to the local ecological and cultural context, highlighting how environmental pressures shape cultural solutions [7].

The study also draws on Disaster Anthropology, particularly the work of Anthony Oliver-Smith, who examines how communities manage and adapt to disasters [8]. Disasters are not just natural events but are deeply shaped by social and cultural factors [8]. In this context, the Minangkabau's traditional knowledge, such as recognizing signs of impending floods and community-based responses, represents culturally embedded disaster management practices. By using this theoretical lens, the study examines how local knowledge contributes to resilience and adaptive strategies in the face of recurring floods.

3 Results and discussion

3.1 History of flooding in Padang

Geographically, Padang City is located in a lowland area that empties into the western coast of Sumatra Island. Historically, when Padang was still a small village, it was dominated by swamp forests and thatch trees, characteristic of flood-prone lowlands. The history of flooding in Padang is also reflected in the names of districts and villages, such as Kampung Pulau Air, Tarandam, Pulau Karam, Rawang, and Ganting, all of which are associated with water, bogs, and floods. The creation of the Banda Bekali flood canal further underscores the longstanding issue of flooding in Padang. This canal was designed to divert the surging waters that frequently inundated Batang Arau, the then center of government and trade for the Dutch East Indies, directing the flow northward to Purus Beach Padang, as shown in Fig. 1.

Fig. 1. Banda Bekali 1920-photo Circa KITLV universiteit qleiden.

Historical records of flooding in Padang can be found in Dutch colonial-era newspapers. For instance, a flood disaster caused by the failure of a flood channel embankment in the northeastern part of Padang on a Friday night [9]. The newspaper published on December 19, 1929, detailed a flood on a Tuesday that raised the Batang Arau's water level by 1.5 meters after half a day of rain. The Dell Courant, on October 20, 1932, reported heavy flooding in Padang due to a full day of rain on a Sunday, which severely affected Kampung Cina (now Pondok), washing away the suspension bridge and the Kampung Durian Power Plant. The water level was estimated to reach 4.4 meters, accompanied by thunderstorms, which also caused landslides that disrupted train operations. Additionally, the Pos Sumatera newspaper on October 21, 1932, reported on floods in Padang that occurred on December 14, June 19, 1931, and October 14, 1932. This publication also documented the efforts of the Dutch East Indies government to address the recurring flooding in Padang City.

3.2 Local knowledge about flooding

Banda Bekali canal, constructed during the Dutch colonial era, represents a significant engineering effort to manage the persistent flooding in Padang. While this infrastructure has been a vital tool in controlling water flow, it does not fully integrate the traditional flood management practices developed by the local Minangkabau community. Local residents, especially those living along the watersheds, possess a deep understanding of natural warning signs, such as changes in water color and the behavior of fish, which are used to predict flooding. This knowledge has been refined over generations, forming an essential part of the community's disaster preparedness [7, 10].

However, there are instances where modern flood management systems, like Banda Bekali, fail to align with this local wisdom. For example, government projects focused on infrastructure often overlook the community's practical knowledge, leading to mismanagement and inefficiency [4, 11]. In some cases, poorly designed or maintained systems have exacerbated flooding, as seen when industrial waste and sediment clog rivers that feed into Banda Bekali, reducing its effectiveness, (Fig. 2) [12]. By disregarding these local insights, flood management efforts risk being less effective, creating further vulnerabilities for communities dependent on their traditional methods for survival [13].

Despite these tensions, there are ways in which local knowledge and modern infrastructure can complement each other. The Minangkabau community's understanding of environmental cues can enhance the functionality of the Banda Bekali system. For instance, integrating local practices—such as planting elephant grass on riverbanks to prevent erosion and using natural indicators for flood warnings—into modern engineering efforts could lead to more sustainable outcomes [13, 14]. Local knowledge systems provide a real-time, flexible response to environmental changes, something that static engineering solutions often lack.

Fig. 2. Conditions of the Batang Kuranji River during heavy rain 2023.

For flood management in Padang to be truly effective, there must be a collaborative approach that respects and integrates both the local wisdom of the community and the technological advancements represented by the Banda Bekali canal. This hybrid model would not only improve flood prevention and response but also strengthen the community's resilience against the increasing challenges posed by environmental changes [15].

Interviews with several informants reveal local knowledge and understanding of the dangers posed by the river. For instance, Mr. Agus explained that if residents are fishing, collecting sand, or engaging in other river-related activities, certain signs indicate impending danger. These signs include the river water becoming turbid or changing color, an increase in floating debris, and the disappearance of fish that previously swam near the surface. These are all indicators of heavy rain in the upper reaches of the river. Similarly, Mr. Hasan, who fishes daily in the Banda Bekali watershed, noted that fish tend to hide and avoid the surface when it is raining or about to rain upstream [16].

An interesting practice among residents who fish around the Banda Bekali watershed is that they do not collect their catch in one place. Instead, they tie the fish with a rope and allow them to swim around the fishing spot, (Fig. 3). This is believed to attract more fish to the area. In some river areas, such as the Banda Bekali watershed, people deliberately plant grasses on the riverbanks and soil mounds in the middle of the river for livestock feed. The grass, often elephant grass (Pennisetum purpureum), is preferred for its large size and sturdy stems, similar to cane stalks Community Interaction with the River

The watershed (DAS) is typically defined as a territory or area bounded by a topographic boundary (ridge) that serves to receive and collect rainwater, sediment, and nutrients, eventually draining them through tributary streams to an estuary. Administratively, the Central Bureau of Statistics categorizes watersheds as villages or kelurahan, with areas primarily consisting of basins or hollows around river flows.

Fig. 3. Fishing activities in the Banda Bekali River 2023.

In discussing watersheds, it is essential to consider the management and activities of the surrounding communities. According to Government Regulation No. 37 of 2014 on Watershed Management, watersheds have land boundaries that serve as topographical separators, and boundaries at sea include water areas influenced by land activities.

Padang City comprises six watersheds:

- The Air Dingin watershed with 10 sub-watersheds spanning 12,874.06 hectares.
- The Kuranji watershed with 20 sub-watersheds totaling 22,852.78 hectares.
- Batang Arau watershed with 13 sub-watersheds covering 17,243.12 hectares.
- The Banda Bekali watershed with 7 sub-watersheds totaling 6,840.68 hectares.
- The Batang Kandih watershed with 10 sub-watersheds covering 7,559.29 hectares.
- Sungai Pisang or Banana River watershed with 4 sub-watersheds covering 2,843.91 hectares.

Community utilization of watersheds involves local knowledge systems that evolve and grow as local wisdom [17]. All forms of community activities that engage with the river follow certain patterns aimed at meeting life's needs. However, the use of watersheds sometimes leads to environmental degradation and increases the risk of flooding [18]. Land conversion into residential areas, construction, industry, and municipal facilities narrows water catchment areas. To understand the happenings within the watershed—such as land use, environmental degradation, flood phenomena, and other systems involving community participation—it is crucial to observe the practices between the community and the river [19].

3.3 Changes in people's interaction with the river

Continuous development and economic growth have altered people's interactions with the river, leading to decreased water quality, a decline in river biota, and a diminishing significance of the river in community life. Economic development and urbanization have drastically reshaped the relationship between communities and their natural environment. Rivers, which were once central to local livelihoods and social life, are now often sidelined as modern infrastructure and industrial projects take precedence [16]. This transition reflects a broader global trend, where rapid economic expansion leads to environmental degradation and marginalization of traditional practices [20].

In the past, people depended on the river for their economic needs. The river played a critical role in the daily lives of many communities, providing water for irrigation, fishing, and other subsistence activities. These rivers served not only as sources of livelihood but also as important cultural and social spaces. Over time, with the advent of new economic opportunities, such as employment in the industrial and service sectors, reliance on river-based economies has diminished.

Now, with the availability of diverse and promising job opportunities, most communities no longer rely on

rivers. The shift in the economic base from agriculture and river-related activities to modern industries has led to a transformation in local economies. Communities that once depended on rivers for fishing, farming, and transportation now find new opportunities in urban centers, significantly reducing their dependence on the river.

The current poor quality of the river has also led to a reduced interaction between the community and the river. Environmental degradation, including pollution from industrial and domestic waste, has further severed the traditional connection between the river and the community. Rivers that were once clean and teeming with life have now become polluted, affecting water quality and diminishing the biodiversity that once thrived in these ecosystems. This decline in environmental quality has also contributed to a loss of community engagement with the river, as it no longer serves as a safe or viable space for work or leisure.

One informant, Agus, mentioned that in the 1980s and 1990s, people were always by the river daily, engaging in work, domestic tasks, and recreation. This historical reflection emphasizes how deeply embedded the river was in the social fabric of the community. People used to rely on rivers not only for economic reasons but also for their daily domestic activities and recreation. The presence of the river fostered a sense of community, where people gathered for washing, bathing, fishing, and socializing [2].

However, from the 2000s to the present, only a handful of people maintain contact with the river, while most simply reside nearby without interaction. As urbanization and industrialization progressed, the community's interaction with the river became increasingly distant. The river, which once served as a focal point for community life, has now become a backdrop to modern living, with fewer people depending on or interacting with it on a regular basis. This disconnection reflects the broader environmental changes occurring in many parts of the world, where rapid economic growth often leads to the neglect of traditional ecological relationships

3.4 Tragedy of human losses that occurred in the river

Izal, someone who lived in DAS, mentioned that the river water used to be very clean and clear. Despite many activities taking place on the river, there was no significant damage to its preservation. Currently, environmental sustainability behavior has eroded due to factory waste disposal, garbage, and land narrowing. These changes in interaction, which reduce community contact with the river, have led to negative impacts.

In mid-June 2022, residents of Padang City were shocked by the tragic drowning of three vocational school students in the Bangek River, located in Lubuk Minturun. Despite extensive search and rescue efforts hampered by persistent heavy rains, two of the students lost their lives. This incident garnered significant public attention due to a local belief that if someone drowns and remains missing, the rain will continue unabated until the body is recovered. This reflects a blend of local ecological knowledge and spiritual beliefs in explaining natural events.

In close proximity to this case, the body of a woman was discovered in the Gunuang Nago Dam, a tributary of the Kuranji Batang River. Interviews with several local informants revealed that the discovery of bodies in rivers is not uncommon in this area. Agus and Izal recounted instances in which bodies were found downstream of the Banda Bekali River in 2011 and 2014, which caused considerable distress among residents. Additionally, Yunita recalled a similar incident around 2004 when the body of an eight-year-old boy was discovered, further highlighting the community's ongoing concerns about safety in the waterways. These events highlight how local knowledge and experiences shape community perceptions of their environment, particularly regarding safety and risk.

According to data on disaster events in the city of Padang from 2016 to 2020, there are several incidents of missing or drifting people in the river, as in the following Table 1:

Table 1. Missing or drifting people data (sources: BPBD and Dinkes Padang City)

Number of Occurrences				
2016	**2017**	**2018**	**2019**	**2020**
12	15	20	4	3

3.5 Community interpretation of rivers

The rivers of Padang City are more than just natural features; they are vital components of the community's identity and daily life. This relationship between the residents and their rivers is shaped by historical, cultural, and environmental factors that underscore the rivers' significance. From providing essential resources for survival to influencing settlement patterns, these waterways have a profound impact on the lives of those who inhabit the region. In this context, the rivers play an integral role in the lives of local residents, shaping their understanding and interactions with their environment.

First, the significance of the river is profound for the residents of Padang, as it is the lifeblood of their existence. Many rely on the river for daily activities, such as washing, fishing, waste collection, and extracting building materials like sand and stone. In some upstream areas, such as the Batu Putuk River in the Kuranji Watershed and the Bangek River, people can still consume the river water, which remains clean and safe for drinking. However, in other locations, river water is often tainted and odorous due to household and industrial waste.

Second, the river also serves as a source of livelihood for many residents. While individuals in the Padang City watersheds engage in various occupations, those linked to

the river are particularly notable. Common livelihoods include farming, mining for sand and stone, and collecting waste. Fishing—whether through traditional methods or more modern techniques—serves as a supplemental source of income. An interesting phenomenon occurs during heavy rainfall, when people flock to the riverbed to catch fish. In these conditions, fish tend to seek calmer waters, making them easier to catch. I have observed individuals of all ages, from children to adults, engaging in fishing activities along the Banda Bekali River, utilizing nets, food serving lids, and long fabrics as tools. The diverse catches often yield large sacks filled with various types and sizes of fish, demonstrating the river's continued abundance.

Third, the concept of settlement in Padang is closely tied to the river. The city features a unique settlement pattern, with residential areas extending along the riverbanks, varying in density from upstream to downstream. Population density tends to be lower in the upstream regions compared to the more densely populated downstream areas. There are generally no houses built directly on the river, primarily due to the frequent flooding experienced in Padang. In contrast, the densely populated and impoverished neighborhoods view the rivers as sources of disease, often relegating them to mere dumping grounds for trash and household waste, further complicating the relationship between the community and their waterways

4 Conclusion

Flood management in Padang requires an integrated approach that combines modern engineering solutions, like the Banda Bekali canal, with the rich local knowledge developed by the community. While Banda Bekali has mitigated flooding to some extent, it cannot replace traditional ecological knowledge that allows residents to predict and respond to floods based on natural signs like water clarity and fish behavior. The tension between modern infrastructure and local practices is evident when government projects overlook this knowledge, resulting in less effective flood control measures, as seen with industrial waste clogging rivers. Integrating local practices, such as planting elephant grass to prevent erosion, can enhance the functionality of modern systems and offer a more adaptive response to environmental changes.

Moving forward, sustainable flood management in Padang will depend on a hybrid model that values both technological innovation and local wisdom. This combined approach not only improves flood prevention but also strengthens the community's resilience, preserving cultural practices that have guided them for generations. As theories like Cultural Ecology and Disaster Anthropology suggest, disaster adaptation must embrace both scientific advancements and the practical, adaptive strategies developed through lived experience.

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