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REGULAR RESEARCH ARTICLE

Rhythms for Living: Fluid Cultural Adaptations within the Dynamic Watersheds of Eastern Indonesia

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ABSTRACT

Tectonics literally and figuratively create rhythms for living in the seismically active nation of Indonesia where shifting plates generate landforms around which cultures construct their homelands. Eastern Indonesian communities who have built their societies around the region's dynamic watersheds have constructed traditional ecological knowledge and place-based skills for accessing freshwater. What is the water-related knowledge and skills of Indigenous societies who live in the tropical monsoon climate zone of Nusa Tenggara Timur Province (NTT)? How have communities living on Sumba Island in southern NTT adapted to their homelands where they find water to pose the most difficult challenge to survival? How do Sumbanese continue adapting to ongoing natural and anthropogenic changes in their island's hydrological systems? Ecological rhythms inform cultural constructions of freshwater ecosystems and the ways people manage water. Despite the dynamism of tectonic and oceanic-atmospheric processes, they are steadier in some ways than misguided anthropogenic developments. We describe changes that have occurred over the past quarter century in the ways Sumbanese interact with and manage freshwater following the premise that socioeconomic transformations coincide with changes in freshwater ecology. We focus on the culturally specific management of water within the North Kodi Subdistrict of the South West Sumba Regency and the hydrological setting of residents' lives. To understand the latter, we reviewed scientific literature and to study the former we conducted ethnographic fieldwork. Our findings show the impacts of hydrological developments on communities reflect existing social structures. In stratified societies, development has uneven impacts. Our research reveals anthropogenic change to be nonlinear. While people may adjust their water-related practices to novel developments, they also may revert to historically proven behaviors when developments fail. Resilience is an inherent quality of cultural adaptations to hydrological systems in the dry tropical biomes of Indonesia.

KEYWORDS

Ethnography; Freshwater ecology; Tropical monsoon climate; Nusa Tenggara Timur Province; Sumba; Social change; Environmental change.

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1. INTRODUCTION: THE DYNAMIC RHYTHMS OF LIFE IN INDONESIA'S RING OF FIRE

Tectonics literally and figuratively create rhythms for living in the seismically active nation of Indonesia where shifting plates generate landforms around which cultures construct their homelands. Winds and currents under the influence of solar energy and climatic conditions, including land and sea surface temperatures, drive oceanic flow through the archipelago and propel monsoonal seasonality. Viewed globally, these forces reveal the integrative influences of hemispheres and continents, atmospheres and surfaces, saltwater and freshwater. The integration of this latter pair manifests as variabilities in the salinity and depths of rivers, wetlands, springs, and ponds driven by

oceanic fluctuations as well as varying volumes of water and siltation shaped by watershed characteristics and precipitation patterns. This article discusses one society's adaptations to Eastern Indonesia's watersheds and how their traditional relationships with water have changed during the 21st Century.

Evaluating cultural adaptation within Eastern Indonesia's evolving ecosystems is the fundamental topic bringing together the four co-authors of this paper. This classical interest intersects with acute concerns about environmental change and infrastructural development. A framework that allows us to consider the longer-term evolution of biophysical settings as well as the shorter-term developments in contemporary communities is needed for ameliorating threats to customary livelihoods within shifting environments. A vital problem within Indigenous societies who are facing political ecological crises is water and the survival of their cultures as freshwater ecosystems transform. Water is an indisputably necessary resource for survival regardless of temporal and spatial variability. Researchers who study in sites where freshwater is extremely limited and where the communities find water to be a primary constraint on their wellbeing are tasked with demonstrating the ways hydrological changes intertwine with sociocultural transformations. As researchers who live and work in semi-arid parts of East Nusa Tenggara Province, the authors of this paper feel a responsibility to present our understandings of the ways Indigenous societies and freshwater ecosystems change relative to one another in Nusa Tenggara Timur Province (NTT).

We have organized this paper to reflect the proposition that integrating the sciences with the social sciences provides an informative model for studying ongoing cultural adaptations to freshwater because the Earth's physical character influences the flow, distribution, and quality of surface water and groundwater, which shape and are shaped by how people perceive and manage freshwater. We bring together these areas of interest in this article by interweaving information about biophysical nature with data about sociocultural livelihoods. After summarizing our research methods in the next section, we discuss cultural adaptations to freshwater ecosystems on Sumba – one of NTT's main islands – highlighting the acquisition of water. This discussion is diachronic because it describes how people's acquisition of water has changed over a 28-year time span from just prior to the new millennium into the second decade of the 21st century. In the course of reading the paper, we hope you will come to know more about Sumba Island and its people; particularly, the members of the Kodi ethnolinguistic group and their system for freshwater management. We believe organizing the paper in this way constructs a model for the integration of anthropology with freshwater ecology.

2. RESEARCH METHODS

For the research we write about in this paper, we used two complementary types of methods: ethnography and literature review. Ethnographic methods enabled the gathering of data about Kodi people's perceptions of and interactions with water. The literature review provided information about geology, hydrology, and climate in NTT. The geographic emphasis of the literature review is on Sumba. Thus, in this paper we evaluate published scientific information in light of our analyses of original data. Here, we describe the ethnographic work that generated the new data for this paper.

The ethnographic data presented in this paper is localized, empirical data gathered in collaboration with people who live in South West Sumba (Smith, 1999). By performing first-hand, on-site fieldwork, we documented the ways freshwater resources have changed since the first author began working in South West Sumba (known as SBD for *Sumba Barat Daya*) in 1997 until the most recent field session in

2025, the reasons why they have changed, and how Sumbanese are managing those changes.

Participation observation and ethnographic interviewing over the course of this long-term project has produced abundant data. Participant observation techniques included accompanying people while they interacted with water and as they moved through their landscapes for water-related purposes. Prior informed consent was obtained for every interview and from the person who shared their knowledge. All participants were adults over 18 years of age. Interviewees and local Kodi research assistants were compensated in materials and/or cash for their contributions to the research.

Information gathered from residents of South West Sumba about water resources takes the form of handwritten fieldnotes, audio/video recordings, and GPS mappings. The content of the fieldnotes and A/V recordings are qualitative information gathered through ethnographic interviews and observations. Fieldnotes and recordings documented the names of water sources, oral histories, myths, and other significant information in Bahasa Indonesia and/or Bahasa Kodi. The notes and recordings are written in a mix of three languages: Kodi, Indonesian, and English.

Through fieldwork, we investigated these questions that we answer in this article: What naturally-occurring and human-constructed water sources exist in SBD? What techniques do residents use to collect freshwater nowadays? How do residents' management of their water requirements differ now from in the past? What changes have occurred over the past 28 years in the ways people interact with freshwater?

Recording knowledge about and practices related to freshwater sites was key to documenting emic viewpoints and establishing etic understandings of environmental baselines as well as their changes through time (Bhateria, 2024). Information about changes in water resources was elicited through observations and interview questions about the water reservoirs people relied on during the stages of their lives and in the places they resided over their life courses; changes they had witnessed in reservoirs during their lifetimes; descriptions of water reservoirs when they were younger and older; similarities and differences in water reservoirs in their gardens, pastures, agroforests, ancestral villages, hamlets, and other places they are familiar with; stories and myths related to water; personal memories from collecting water; and future aspirations regarding access to freshwater.

A strength of ethnographic research methods is the ability to learn many details about a local community and their landscape. Ethnography requires intensive work in a delimited geographical space (Dasion & Nugroho, 2020). The ethnographic research methods we used to collect the data presented in this paper lead us to focus on the communities who reside in three watersheds within the Kodi region of SBD. These watersheds are the Bondo Kodi River, the Wai Ha River, and Kori River. Conceptualizing Kodi society as a collective of people whose homelands take the form of watersheds enables us to contextualize cultural change within this place's hydrological setting. We visualize Kodi society as a collective of people who interact with freshwater in culturally, historically, and ecologically specific ways.

Now that we have shared our research methods, in the next sections we discuss people's interactions with freshwater ecosystems and how they have changed during the previous 28 years. The year set as the environmental baseline (Bhateria, 2024) for evaluating the entanglements of cultural and ecological processes is 1997 because that is the year when the first author [Fowler] began doing ethnographic research in Kodi. Thus, we have curated data gathered, using the techniques of participant observation and interviewing, about people's interactions with water for nearly three decades. In the sections that follow, we have interwoven our analyses of this data with

geological and hydrological information derived from the publications of scientists who work in those disciplines. We believe combining information from the literature review with our own ethnographic information enables us to link the culture of an island community with the aquatic features that define their homeland. Combining multiple disciplines' findings provides us with a window into perceptions of and relationships with water in Kodi society. As an outcome, we learn about Kodi People's evaluations of the changes happening with their hydrological systems as well as their ideas and strategies for adjusting to those changes.

3. THE CULTURAL CONSTRUCTION OF KODINESE WATER RESERVOIRS

Freshwater provisioning – with all its tangible and intangible characteristics – is one manifestation of the mélange of socioecological processes that constitute Kodi society. Kodi is a creolized society (Fowler, 1999) consisting of elements amalgamated from internal and external influences (Kirch, 2000). Pre-Austronesian, Papuan, Austronesian, Dutch and other European, Indonesian, and globalized constituents of language, subsistence, kinship, exchange, religion, ethnohistory, crafts, symbolism, and identity are actively assembled into the creolized collective named Kodi (Bellwood, 1997; Fowler, 1999; Lansing, 2007; Hägerdal, 2024; Oemboe Hina Kapita, 1976; van Heekeren, 1956). This creole society has their own Indigenous mode for culturally constructing ecological elements in their homeland; the example that is most relevant to this paper is the unique aquatic structure of their own raised coral reef. Their knowledge about water as well as ways of relating to and interacting with water constitutes a one-of-a-kind, resilient, dynamic system. In the following sections, we present a partial version of the Kodi culture's construction of freshwater based on our having listened to its members talk about water and having accompanied them as they accessed water. As we relay the emic perspective, we also present the etic perspective based on observations combined with our evaluation of scientific publications about Sumba's environment.

3.1 From catchments to communities

Generally, across the Kodi region – which we might consider to be the macro-level with the meso-level being a watershed – some aspects of freshwater access have remained consistent over the 21st Century while other aspects have changed. If we zoom in to the micro-level of specific villages, hamlets, households, and collectives, we find that access to water is variable depending on social and ecological conditions. Changes in the quality and quantity of freshwater take place within the context of changing social, political, economic, and ecological conditions. One example of links between hydrological and political economic change is a temporary shift for numerous households to access water from manufactured utilities installed by Pro Air, which we discuss further below. An example of links between hydrological and ecological shifts is the remarkable variations in precipitation associated with fluctuations in climate and weather.

Fluctuating climate and weather conditions result in variations in the quantity and quality of rainwater. Rainfall varies across shorter and longer time periods under the influence of the annual monsoons and the cyclical ENSO and Indian Ocean Dipole. Annual precipitation ranged across the island from 3721 to 661 mm/year in the years from 1998 to 2009 (Authemayou et al., 2018). In that same time range, the months with the greatest average rainfall were December through March while the months with the least amount of rainfall were May through October. Double monsoons shape the Dry Season when the dryer, cooler southeast Australian monsoon occurs from May through October. The Rainy Season happens when the wetter, warmer northwest Asian

monsoon blows through from April through November. Seasonally, average rainfall was higher during the Rainy Seasons with an average of 1,449 millimeters between 1991 and 2001 (Walker et al. 2005) with year-to-year variability.

ENSO and the Indian Ocean Dipole are two cyclical climatic phenomena that affect precipitation on Sumba. In 1997, precipitation was sparse due to a combination of a severe El Niño and a positive Indian Ocean Dipole; not only was the amount of rainwater available for capture lower or available for a shorter period in a shortened rainy season, but also water levels were lower in springs, streams, and ponds. In 2022, precipitation was abundant due to a strong La Niña and a negative Indian Ocean Dipole; some locations experienced flooding, and sedimentation was heavy. In 2025, a neutral ENSO and a neutral Indian Ocean Dipole extended the rainy season – and thus the time when people had rainwater for domestic use – into early-June.

In Sumba's predominately karst hydrology, precipitation accumulates in surface water (streams, caverns, fissures, caves, springs, sinkholes, dolines with ponds) and groundwater (aquifers formed from limestone, tuff, marl, and gravel). Rainwater is the main source of water during the rainy season for most residents in the North Kodi Subdistrict, according to the findings from our ethnographic fieldwork. Rainwater is essentially free and available to anyone who has the tools to capture it. However, reliance on rainfall varies depending on precipitation patterns and the availability of alternative water sources. The percentage of people capturing rain for household use is lower during times with no rain (such as the Dry Season) and higher when rain falls (especially during the Rainy Season). When rainfall is available, many householders who live in North Kodi's villages and hamlets capture rainwater using a variety of containers to channel water draining from the eaves of alang grass or metal roofs. Gutters, made from bamboo or similar materials, direct water from roofs to containers at some houses. Figure 1 shows an example of one household's rainwater capture system, in this case consisting of gutters made from bamboo held together with twine positioned to direct water into a concrete cistern covered with metal panels. In the North Kodi Subdistrict, rainwater and surface water have consistently served householders' primary needs across the previous 28 years. Householders rely heavily on rainwater during the Rainy Season and also on springs and streams throughout the year, according to our ethnographic data. For nearly three decades – even while water and electric utility systems were installed, cisterns were constructed, and tanker transport businesses were organized in the intervening years, as we discuss below – Kodinese find their original forms of adaptation to the island's hydrology and climate to be the most sustainable.

Figure 1. A rainwater capture system channeling water draining from an alang grass roof into a concrete holding tank. Photo taken by the first author.

3.2 The watersheds of the South West Sumba Regency

The residents of Sumba's watersheds interpret the landscape through their cultural lens and engage with aquatic systems using practices rooted within their cultures that have immense historical depth on the island.[1] Political, economic, and social influences internal to local communities and brought to the island by Kodinese or imported by external agents from nongovernmental, state, multilateral and other operations also shape Sumbanese relationships and interactions within watersheds. The watersheds are themselves agents who are affected by and who affect people's activities. Watersheds are available for people's meaning making and for playing roles in social reproduction. Here in this section, we present some information about the island's watersheds because they have pivotal roles in hydrosocial relationships.

Sumba's watersheds originate near a central fault line that divides the island into a southern flank and a northern flank as it runs from East to West. This fault line determines drainage patterns on Sumba. In Figure 2, the fault line is marked with a red line indicating "Normal Fault." In the top half of Figure 3, the main fault line is marked in white as a "Fault" and in the bottom half of Figure 3 with a black line indicating "Current Water Divide from Satellite Image" (Authemayou et al., 2018). Rivers located south of the fault line flow southwards towards the Indian Ocean. Rivers originating north of the fault line flow either northwards towards the Sumba Strait (in the west) or empty into the Savu Sea (in the east). Notice the rivers flowing to the north and south from the main fault line in Figures 2 and 3.

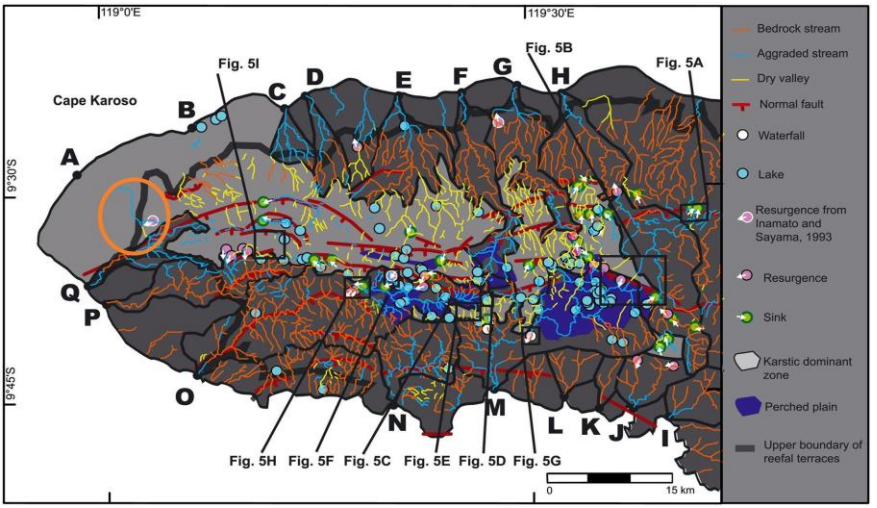

Figure 2. "Geomorphologic map of drainage dynamics and tectonics features mapped from satellite images on GoogleEarth Software V7.1.7.2606 (http://www.earth.google.com)" [Source: Authemayou et al. 2018 with copyright permission provided by John Wiley and Sons, Inc. Copyright © 2018 John Wiley & Sons, Ltd.[2]]

[1]Island Southeast Asia is thought to have been inhabited by archaic hominins for as many as 1.5 million years (Hakim et al. 2025); pre-Austronesian, *Homo sapiens* for at least 42,000-45,000 years (O'Connell & Allen, 2004); and Austronesian farmers for 3500-4,000 years (Bellwood, 1997; van Heekeren, 1956).

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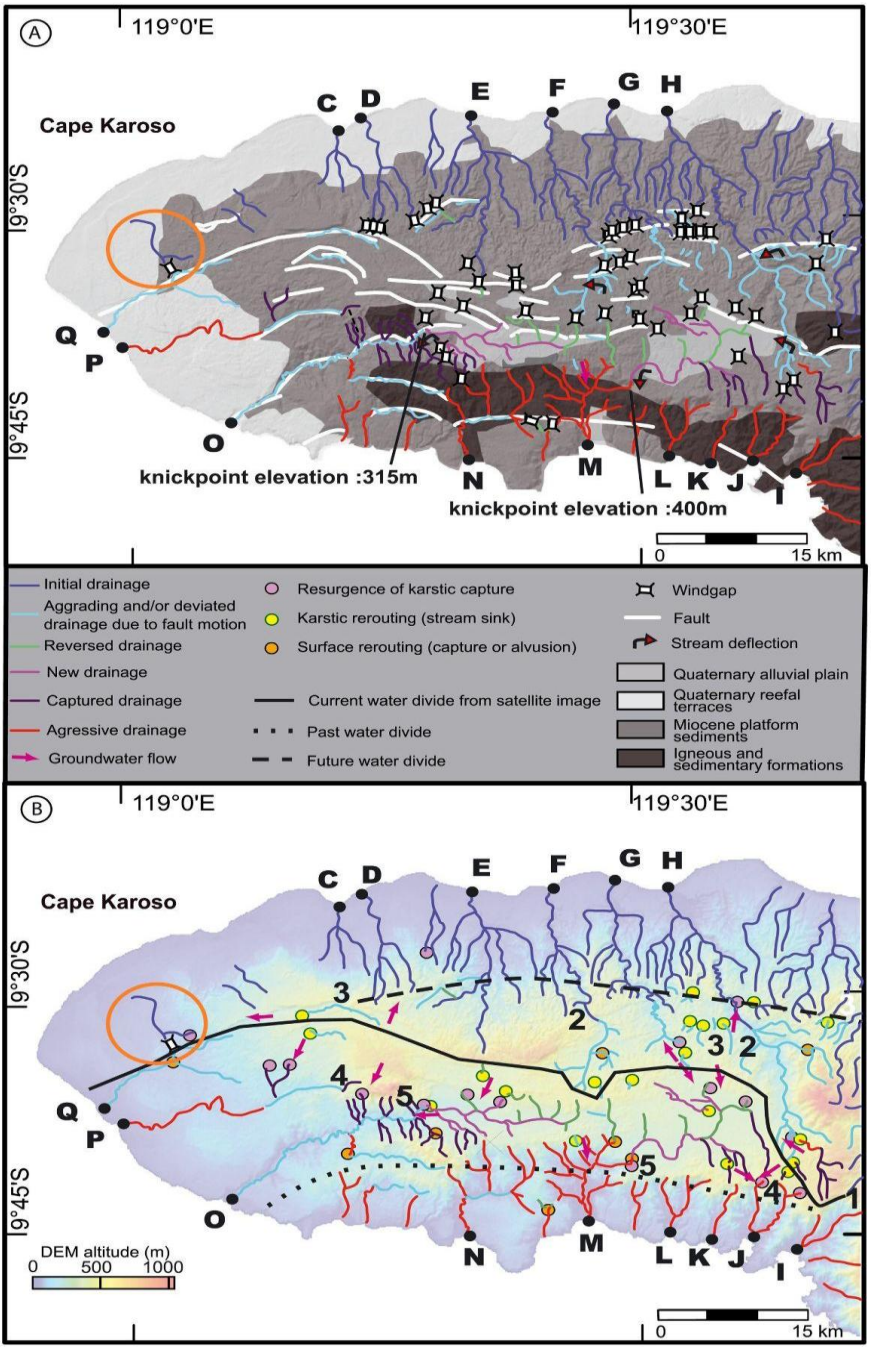

Figure 3. "Drainage rearrangement of western Sumba" [Source: Authemayou et al., 2018 with copyright permission provided by John Wiley and Sons, Inc. Copyright © 2018 John Wiley & Sons, Ltd.]

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The area surrounding the main fault line is the most karstified sector of the island and the area with the highest precipitation. These two traits impact watershed dynamics and stream behavior. As rivers traverse the karstic landscape,[3] they alternately rise to the earth's surface and drop back underground and are therefore intermittently visible and their waters discontinuously available to people. Resurfacing of streams happens through caves, caverns, fissures, waterfalls, and springs, and occurs in dolines and sinkholes.[4] Some streams empty into the ocean, others terminate in sinkholes, ponds, or lakes, and others descend back under ground. While the larger rivers flow year-round, secondary streams flow intermittently as they align with precipitation patterns. Numerous sites where people access water are located within drainage basins and take the forms of main channels, secondary tributaries, springs, sinkholes, and ponds.

3.3.1 Kodi's southern drainage basins

Three of the larger watersheds in the southern flank of the Kodi region drain into the Indian Ocean. We identify these rivers as the *Pola Pare* (O in Figure 2), the *Wai Ha* (P in Figure 2), and *Bondo Kodi* (Q in Figure 2). The headwaters of these rivers are near the boundaries between the Quaternary reefal terraces and the Miocene platform sediments. While the rivers cross geological boundaries, they also cross ethnolinguistic boundaries with the one more relevant to this article being between the domains of Kodi and Wejewa. Along their courses towards the coast, the names of these rivers change. Factors leading to alternate names given to a river may be 1) naming practices reflect communities' cultural, social, historical, political, and/or economic considerations, 2) the river crosses boundaries of the homelands of distinct ethnolinguistic groups and/or subgroups, 3) in the karstic landscape, the rivers appear and disappear from the island's surface along their courses and their resurfacings explain the renamings, and/or 4) the river's branches converge and the new confluence is given a different name from its tributaries.

The main channel in the 310 km^2 Pola Pare basin (Monk et al., 1997) is named *Pola Pare River* by the community situated at its mouth at the edge of the Indian Ocean. For most of its course, the Pola Pare River is a bedrock stream, as indicated by its orange color in Figure 2. It becomes an aggraded stream, indicated by blue in Figure 2, close to the ocean.

The Wai Ha River drains into the Indian Ocean near Ratenggaro Village, where one name for this river is *Wai Ha*, another name is the *Belogor River*, and people may call it by other names at its mouth. From the upstream segments down to the ocean, the river has numerous names. The Wai Ha River is a bedrock stream from its mouth towards its inland headwaters. Several of the upland tributaries feeding into the Wai Ha are aggraded streams where the streams' elevation has risen over time due to sediment accumulation. Monk et al. (1997) identify a 542 km^2 catchment area in the west, but it is unclear whether that identifies the Bondo Kodi River, the Wai Ha River, or both combined.

The watershed of the Bondo Kodi River covers a portion of western Sumba to the north of the Wai Ha watershed. *Bondo Kodi* is the name given to the river by the communities who live around its mouth at the Indian Ocean; for example, the folks portrayed in Figure 4 who are bathing, washing clothes, collecting water, and playing in the evening. Moving upstream from the river mouth, the Bondo Kodi River is known

[3] Twenty percent of the Earth's surface above sea level and 10-15% of the land in Southeast Asia is carbonate (Authemayou et al. 2018).

[4] Sinkholes are where the Earth's surface collapses to form basins containing groundwater that is exposed or that rises up from aquifers.

locally as *Lolo Kalayo*, *Nundu Kaha*, *Watu Mete*, and possibly additional alternate names. Part of the Bondo Kodi River is an aggraded stream (its blue sections shown in Figure 2), part is a bedrock stream (its orange section in Figure 2). The bedrock section of the Bondo Kodi River traces the island's main fault line. Figure 3 shows the Bondo Kodi River as being an aggraded or deviated stream as indicated by the light blue color (Authemayou et al. 2018). 'Deviated stream' means that its current location could be a shifted version of its original location and the shift may have occurred due to the actions of tectonics and uplift (Gelder et al. 2023).

Figure 4. Community members bathe, wash clothes, collect drinking water, and play in a popular access site on a bend in the Bondo Kodi River.

3.3.2 Kodi's northern watersheds

Numerous bedrock streams that flow northward toward the Sumba Strait are located on the northern side of the central fault line in South West Sumba. This region has high karstification and probably contains some underground streams as well as ones that intermittently surface after flowing underground. Some of these northern-flank waterways belong to a large third watershed within South West Sumba. This watershed encompasses a 1073 km^2 catchment area (Monk et al., 1997) spanning across the ethnolinguistic domains of Kodi, Bukambero, Laoura, and Wejewa.

The Kori River, a northern flank waterway, is/was one of the main rivers in Kodi. The Kori River is an aggraded stream, fed by an eastern branch and a western branch that merge into one as they flow northward toward the Sumba Strait before sinking into the karstified reef terraces prior to reaching the ocean. These two branches of the Kori River are visible in Figures 2 and 3 where the authors of this paper have added orange circles around the Kori River as a means for highlighting its relevance in our research. In the original Figure 2 (by Authemayou et al., 2018), a Resurgence icon shows where the Kori River resurfaces after having flowed underground for some distance. In the original version of Figure 3 (by Authemayou et al., 2018), the Windgap icon marks the location of the western branch, which originates on the north side of a dry valley that straddles

the central fault/drainage divide in Kodi. A wind gap occurs where a river has eroded a channel through a ridge, the river subsequently disappears, and a dry valley takes its place. Wind gaps are a type of "diagnostic geomorphological feature" of river diversions (Authemayou et al., 2018: 1892) providing evidence of historic changes in river channels.[5] In Figure 2, the eastern branch and main confluence appears in blue while the western branch appears in yellow indicating it is dry.

Figure 5. The Kori River Bed Empty of Water in the Late-Dry Season. Photo by the first author.

The communities who live around the dry, western branch of the Kori River have stories about its transition from being full of water to becoming a dry riverbed. They often recall when the Kori River served as their main source of freshwater, and their stories talk about the drying up of the river and the impact on their lives. The Kori River, they say, is empty except when it rains and at those times muddy runoff accumulates in the drainage. Figure 5 portrays the riverbed when it was empty of water during the late-Dry Season. The vegetation in the channel and along its banks is from bamboo residents slashed and discarded there. Figure 6 is a photo taken during the early-Wet Season when the riverbed contained muddy runoff. According to oral history, the Kori River previously flowed year-round but has stopped flowing three times since the early colonial era. Two of those times, the year-round flow recommenced, but the year-round flow has not yet returned since the third time it ceased, which was approximately between 2010 and 2012. This feature of Sumba's watersheds has profound implications for the communities who lose their main water supply due to diversion. Folks who previously collected water in the Kori River are working towards adjusting to the absence of this vital source around which they had built their lives.

Figures 2 and 3 are created by Authemayou and co-authors based on their excellent research in the sciences of tectonics, geodynamics, and structural geology. We appreciate their expertise and the agreement of their publishers, John Wiley and Sons, in permitting us to reproduce the figures here. The social science of anthropology together with ethnography and local knowledge enables us to further enhance Authemayou et al.'s illustrations by providing a cultural perspective on geodynamics. Vice versa, these figures support our ethnographic project by explaining scientifically what we hear from watershed residents and demonstrating the value of interdisciplinary work. Below, we further explore the social implications of, and cultural adjustments to, the dynamics of river drainages and the geology of the island.

[5] Another diagnostic feature of river diversion is an elbow in the river, which is "produced by the rerouting of streams along fault scarps" (Authemayou et al. 2018: 1892).

Figure 6. The Kori River Bed Containing Muddy Runoff in the Early-Wet Season. Photo by the first author.

3.3 Springs and ponds

Key features of Sumba's watersheds, in addition to rivers, are springs and ponds. Serving as vital freshwater reservoirs for islanders, springs and ponds are distributed across the landscape from the north where rainfall seasonality is more abundant all the way around the western and southern curve of the island along the ocean's edges where water volumes fluctuate with seasonal precipitation patterns. Figure 7 provides an image of a pond on the North Kodi coastal plain. Two springs that are infamous among residents of western Sumba for their abundance are Waikabubak and Waikelo. Waikabubak flows at a rate of 1000 l/s as it emerges from within the Waikabubak Formation that consists of chalky or clayey limestone, sandy matrix, tuffaceous marls, and tuff. Another example is Waikelo, which flows at a rate of 1000 l/s out of a limestone aquifer (Inamoto and Sayama 1993). Waikelo is an example of a point of resurgence, where the water emerges from underground through a cave – as portrayed in Figure 8 – and tumbles down a waterfall into the farmed floodplains below. Waikabubak and Waikelo are two of the nine bigger springs – defined as those providing more than 100 l/s – according to Inamoto & Sayama (1993), who calculate there to be 43 moderate sized springs with between 5 and 100 l/s, and 72 springs with flows between 5 and 1 l/s for a total of 124 springs island-wide.

Figure 7. A Pond on the Coastal Plains of the North Kodi Subdistrict. Photo by the first author.

The volume of water in Sumba's freshwater ecosystems varies, as previously noted, depending upon precipitation. Precipitation patterns cause changes in the volume of ponds and springs, as well as streams and aquifers. Precipitation deposits water directly into a river's headwaters and increases flows into the river via its tributaries. Precipitation patterns affect turbidity with greater rainfall increasing sedimentation and less rainfall decreasing sedimentation. Land conditions, including those shaped by anthropogenic developments, can also impact the runoff of sediment into rivers. Precipitation is linked to people's interactions with springs, ponds, rivers, and streams in ways that profoundly impact their lives as well as the biophysical characteristics of freshwater ecosystems.

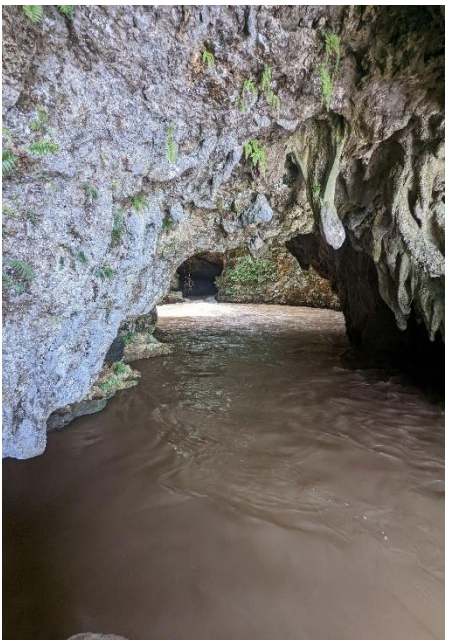

Figure 8. Waikelo, a Resurgence in South West Sumba's Karst Landscape. Photo by the first author.

While precipitation causes variability through time in the water volume across the north-south and east-west gradients, tidal fluctuations change water volumes as well as salinity in freshwater ecosystems closer to the ocean within the tidal zone. Ocean tides cause variations in water levels and salinity. As the tide rises, saltwater proceeds upstream to the far reaches of tidal inundation and as the tide recedes, the saltwater goes out causing decreases in salinity and water levels. Salinity impacts freshwater reservoirs in the tidal zone more than those further inland. For those freshwater reservoirs within the reach of the tides, knowledge about the saltiness of the water and its connections with tidal variability is shared by residents of the region. Being familiar with coastal areas means knowing how to time water collection at lower tides to get the least salty water and when to avoid springs at higher tide levels because the water is saltier.

Sumbanese traditional ecological knowledge related to freshwater and saltwater has evolved over many millennia. Oral history attests to the centrality of water in Sumbanese settlement patterns. "The ancestors only built their villages in places where freshwater was available," according to one of our interviewees. The archaeological record also provides evidence for the co-evolution of Sumbanese agropastoralism and the island's hydrological architecture. In recounting their oral histories, today's residents talk about their earliest ancestors on the island, saying they settled alongside rivers and mention Sasar on the north-central coast. Some of the oldest archaeological evidence from Sumba comes from Austronesian communities who lived alongside rivers on the north-central coast plain at sites named Wunga, Mboro Baku, Kambaniru, Lambanapu, and Melolo (Handini et al., 2023: 4). Information about pre-Austronesian settlement is not yet available due to a deficit of archaeological research on the island.

For many generations, Sumbanese social reproduction has taken place alongside hydrological dynamics. We anticipate future generations will experience continuing and possibly increased needs to adjust to saltwater inundation of freshwater reservoirs.

Sea level rise will likely lead to the submergence of more coastal plains and coral reef terraces on the island within the upcoming years. Mean sea level rise globally over the upcoming 70 years is expected to continue to outpace the rate at which the island has been uplifted during the previous 2.8 million years of the Quaternary Period. (We provide more information about uplift in the next section.) Freshwater ecosystems will be impacted by saltwater inundation further than they currently are, even though it would be hopeful to view uplift as a defense against rising seas.

4. UPLIFTING THE CORAL REEF ISLAND OF SUMBA

In this section of the paper, we discuss the tectonics of the region for the purpose of better understanding island architecture relative to oceanic processes and hydrological systems. Sumba Island is a carbonate platform that has been uplifted above sea level by tectonic activities. The eastern flank of Sumba emerged above sea level less than 3 mya and the northern portion rose above sea level about 1.0 – 1.6 mya (Authemayou et al., 2018; Chauveau et al., 2021; Pirazzoli et al., 1993). Interestingly, this was the same period when *Homo erectus* reached Java 1.0-1.8 million years ago, shortly after that island had emerged above sea level and became connected to Sundaland. These *Homo erectus*, who had been present on Sundaland since 7-6.2 mya, could walk to Java. No land bridges connected Sumba to Sundaland at that time.

The portion of Sumba Island that is above sea level is the very top of the ridge on a much larger landmass (Reed et al., 1987). Most of the landmass is submerged under the ocean and consists of thick crust lifted in the outer forearc. Sumba sits east of a subduction zone where the Indo-Australian oceanic lithosphere subducts under the Indonesian arc lithosphere (sometimes referred to as the Eurasian plate) and west of a collision zone with the island and a volcanic arc-continent where the Banda Island arc (also known as the Sunda intraoceanic arc) collides with the northwestern sector of the Australian continental lithosphere. Major tectonic features surround Sumba Island with the Java Trench on the southwest, the Timor Trough on the southeast, the Savu collision zone on the east, the Flores Fault to the northeast, and the Sunda volcanic arc to the northwest.

The Sumba Ridge forms a barrier between the Savu Basin to the east and the Lombok Basin to the west (Reed et al., 1987). The eastern side of the Sumba Ridge drops down into the Sumba Basin and farther east beyond that rises again to form the Savu-Timor Ridge. The Sumba Ridge and the Sawu-Timor Ridge in this forearc region forms a barrier to the Indonesian Throughflow as it moves to the southwest from the Pacific Ocean into the Indian Ocean (Reed et al., 1987). The Pacific Deep Water (1-1.5 km deep) currents work to pass through the barrier and thereby exert strong erosional force on the ridges resulting in the Sumba Drift, a 120 km long x 20 km wide mound of sediment on the ocean floor that is 700-1000 meters thick. This deposit consists of calcareous clays, foraminiferous ooze, and quartz and feldspar silt that were eroded from the Sumba Ridge and Sawu-Timor Ridge and deposited in the Sumba Basin. A gap has formed where the water overflows due to the strength of the deep currents and the narrowness of the corridor between the ridges. During the northwestern monsoon season, storms impacting the deep water can increase the vigor of the Indonesian Throughflow.

On the above-sea-level section of the Sumba Ridge, volcanic rock from the Cretaceous Era (145.5-65.5 mya) and Early Oligocene (33.9-23.3 mya) underline the Central and Western regions indicating volcanic activity from 86-31 mya (Keep et al., 1993; Rutherford et al., 2001). Volcanic rocks and marine sedimentary rocks – particularly limestones, marls, and foraminferal marls – accumulated on these volcanic rocks until the Pliocene (5.0-2.2 mya). Overlaying these basement rocks are reef

limestone and alluvium from the Quaternary (2.58 mya – present) (Authemayou et al., 2018; Inamoto & Sayama, 1993; Rutherford et al., 2001). The marine sedimentary rocks – mostly originating from coral reefs – are dominated by limestone and include sandstone and tuff. Karst and coastal terraces have formed where the marine sedimentary rocks occur.

The subduction of the Indo-Australian oceanic lithosphere and the Australian continental crust continued uplifting the island in the transition from the Pleistocene (2.58 mya - 11.7 ka) into the Holocene (11.7 ka – present). The uplift rate for the coral reef terraces in the northeast at Cape Laundi has ranged between 0.5 to 0.65 mm/year thereby raising the ground to roughly 450 masl since the interglacial era (De Gelder et al., 2023). At Tambolaka, the capital of South West Sumba, the uplift rate during the Quaternary Period is slightly less at 0.15–0.175 mm/year (De Gelder et al., 2023).

Even as sea levels rose with the warming climate, this island has stayed above water. However, historic rates of uplift are less than historic rates of global mean sea level rise. The global mean (average) sea level rise between 1993 and 2010 was 3.2 mm/year (ranging from 2.8–3.6 mm/year) (IPCC, 2014). This was 2.625 mm/year more than Cape Laundi's mean (average) uplift rate of 0.575 mm/year and 3.0375 mm/year higher than Tambolaka's mean (average) uplift rate of 0.1625.

In the period between 2030 and 2100, the IPCC (IPCC, 2014) predicts that global mean sea level rise will range from 260 to 550 mm in the lower emission scenario (RCP2.6) and 450 to 820 mm in the higher emission scenario (RCP8.5). Under the lower emission IPCC scenario, net inundation at Cape Laundi would be 195 – 535 mm and 245 – 532.5 mm in Tambolaka. At Cape Laundi where uplift is faster at 0.65 mm/year, sea level rise would be approximately 911.7 mm by 2100, according to RCP 2.6. At Tambolaka with its slower uplift rate of 0.15 mm/year, net sea level rise in the RCP 2.6 scenario would be 961.7 mm.

5. AN ENGINEERED HYDROLOGICAL INFRASTRUCTURE FOR THE 21ST CENTURY

Now that the groundwork has been laid for conceptualizing the island's hydrological structure in relation to where people access its naturally occurring water resources, we turn to describing another set of water provisioning facilities: 21st Century systems built by people. To preface this, we must recognize that people have been engineering many of Sumba's so-called 'naturally occurring' reservoirs for many generations. Oral history includes stories about protecting water sources, restricting access, designating prohibited and permitted activities at reservoirs, deepening springs, creating paths to access reservoirs, arranging rocks, constructing dams to pool water, using containers to pull water up from hand-dug wells, and making other types of alterations. Many reservoirs have storied meanings in Kodi culture and many of the meanings associated with freshwater sites are connected to the ancestors' exploits. These dimensions of freshwater are ones we write about elsewhere because our focus in this paper is on the ecological and technological traits of freshwater ecosystems. Whereas we described the 'naturally occurring' sources (while simultaneously recognizing some human interventions as being 'natural') at other points in this paper, here in this section we discuss the main engineered types of infrastructure and people's experiences with them. More specifically, we discuss components of the fabricated water infrastructure that have been developing in Kodi during the 21st Century.

Freshwater is available to Kodinese in several types of engineered systems, as well as from the naturally occurring sources of rainfall and surface water described above. The infrastructure that has been built and/or installed in Kodi during the recent decades includes bore wells, cisterns, metal pipe networks, household faucets, public fountains, and kiosks.

Kodi residents have increased their consumption of water from bore wells over the past three decades. The number of wells in Kodi has increased over time and that increase has accelerated in the past 10 years. Inamoto & Sayama (1993) listed 3 wells that were operating in 1989-90.[6] One well was in Ande Ate (60 feet deep, date of construction is unknown), another in Lokoli (36 feet deep, drilled in 1985), and a third in Pemuda (60 feet deep, drilled in 1975). In 1997, another well was operating near Hamonggo Lele. In 2014, a well had been drilled in Mogha Kawongo, but was not operating because residents could not afford to fuel the pump or repair breaks. World Vision drilled two wells in 2017-18 in Kapaka Madeta and Koki (We Are Water Foundation, 2025). In 2025, several additional wells were operating, including one in Kori, two in Manganipi, two in Waipanoka, one in Hamonggo Lele, and additional ones in Bondo Kodi and elsewhere.

People access water from bore wells in several ways. One is direct access, where those who need water will go to the wells themselves and fill their own containers to replenish their supplies at home. Another is via tanker delivery where householders pay tankers to deliver well water into their cisterns. Two forms of exchange at play in the water economy are those embedded in traditional social networks and those operating in a commercialized system. The commercialized economy is facilitated by water distribution companies and involves bore wells, tanker trucks, and storage tanks. Tanker trucks fill up at wells, haul the water to households and hamlets at various distances away, and then transfer the water into cisterns adjacent to houses and hamlets. The tankers belong to water delivery businesses, the number of which has increased as the number of wells, holding tanks, and customers have increased. Some tanker delivery businesses own wells. Other tanker delivery businesses own tankers but not wells and thus purchase water from well owners to resell to householders with cisterns. Many tanker drivers are paid for driving (such as the Beautiful Life driver in Figure 9), but do not own trucks or wells.

Figure 9. A Driver for Beautiful Life, a Water Delivery Business. Photo by the first author.

An example of a tanker emptying a delivery order into a cistern is shown in Figure 10. Some cisterns used for storing well water are claimed by individual households and some are shared by multiple households. Most cisterns are above-ground, square or rectangular tanks made of concrete. Some households and organizations are installing

[6] All three were sited in Kalianga Formation soils consisting of reefal limestone with a sandy matrix.

above ground plastic containers as well. Many cisterns capture rainwater as well using gutters, as shown in Figure 1. For folks who own wells and sell water in them, their sales are higher during the Dry Season than during the Rainy Season when people who have cisterns rely more heavily on the rainwater that requires no cash to accumulate. For those who do not own wells, rainwater is available for free but well water is acquired according to the terms of the traditional or commercial exchange system.

Figure 10. Tanker Truck Dispensing Freshwater into the Concrete Holding Tank of a Household. Photo by the first author.

Figure 11. Pipes Drawing Water from the Headwaters of a Creek on Sumba. Photo by the first author.

Another type of engineered system in Kodi is the network of water pipes and pumps known among Kodi speakers as "Pro Air." Pro Air is a multilateral project involving PAMSIMAS (Community Based Rural Water Supply and Sanitation Program, also known as the National Rural Water Supply Project), and several other governmental agencies and nongovernmental organizations including both Indonesian and foreign entities. Pro Air is a 21st century system for distributing water that uses gravity, solar-powered pumps, or a combination of the two to deliver water through pipes from upriver sources to downstream outlets where people can access the water. Figure 11 is a photo of a set of pipes carrying water out of a spring through the power from a pump located uphill from it, which subsequently passes the water along to householders at lower elevations. The Pro Air infrastructure is designed to enable people to collect water at sites closer to their homes and thereby reduce the time and labor

required for traveling to the streams and springs themselves. Community members access water from three types of taps: water kiosks on roadsides, faucets in the yards of individual houses or clusters of homes, and public fountains. Figure 12 shows a public fountain built along the roadside next to a Village Office (*Kantor Desa*) where it was accessible to residents of the surrounding hamlets.

The specific fountain shown in Figure 12 was working in 2023, but, by 2025, the faucet had been removed because the pipes to the spring were broken and no replacement materials nor funds to buy them were available. Like this and other public fountains with piped networks feeding them, some water supplies from kiosks had also failed. This kiosk shown in Figure 13 was working intermittently in 2023 and, by 2025, was defunct. Pro Air abandoned its projects during 2020, according to Kodi residents. Unfortunately, many of the kiosks and fountains suffered similar fates. Access to some types of engineered systems has been inconsistent because the technology has failed for various reasons and subsequently abandoned in some cases. This is the reality Kodi People have faced and been forced to adapt to, in some cases by returning to greater reliance on naturally occurring sources and in other cases by shifting to using cisterns and sometimes also purchasing water and paying for its delivery through tanker services.

Figure 12. A Faucet for Collective Use Near a Village Office. Photo by the first author.

Figure 13. A Water Kiosk Constructed by Pro Air and Intermittently Working or Broken. Photo by the first author.

5.1 Anthropogenic drivers in watershed dynamics

Generalizing across the region, Kodi People have a wider variety of sources for freshwater compared with the late-20th century and times prior, even while they tested some of these sources through trial-and-error as introduced technologies come-and-go. One thing that has been consistent is that accessing water plays out within an existing social structure. Another through-line is that changes in hydrological systems and changes in social structure impact one another.

To look more deeply at uneven change, we can compare residents of two adjacent villages, Waiholo and Wailabubur where the variability in people's experiences is evident. In 1997, nearly 100% of the 3,133 residents of Waiholo Village[7] relied upon springs, streams, and rainwater for their primary supplies. The one exception was a household in Lentoro Hamlet with a member who was the head of the village health

[7] The population trend in Waiholo between 1997 and 2020 is unclear because, according to one source, the population of Waiholo declined by 11% (from 3,133 to 2,800 individuals) while, according to another source, the population increased by 26% (from 3,133 to 4,226). Satyanugraha et al. (2022) is the source which shows a population decline for Waiholo. Satyanugraha et al. report 700 as the number of households and 2800 as the number of individuals in Waiholo in 2020. Pandak, a resident of Waiholo, reported the population to have increased from 3,133 in 1997 to 4,226 individuals in 700 households in the 2020 census.

clinic. Income from his employment enabled the family to construct a concrete cistern for capturing and storing rainwater. In 2025, his widow occasionally purchased water for the cistern when rainwater was not available. In 2022, 100% of Waiholo's residents reported that they continued using rainfall, springs, streams, and ponds, according to a survey we conducted that year. Figure 14 is a photo taken in 2025 of one of the local springs in active use. During a fieldwork session at the end of the Rainy Season in 2025, Waiholo residents shared with us that they continue to capture rainwater and to collect water from springs and streams even during the Rainy Season.

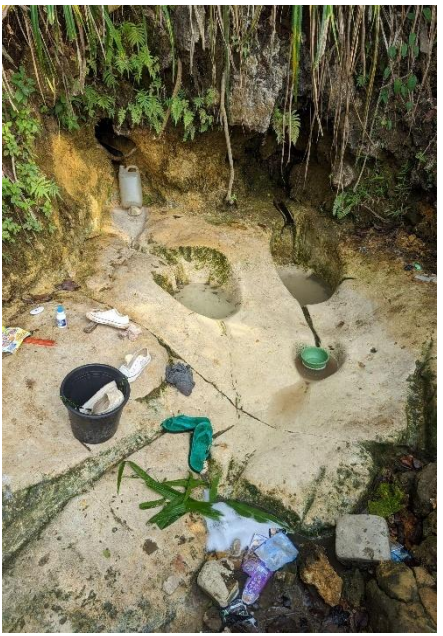

Figure 14. Spring in Kodi Serving as a Vital Point for Accessing Freshwater. Photo by the first author.

Compare the findings of Waiholo to the results from our survey in nearby Wailabubur Village. Similarly to Waiholo, naturally occurring sources served the needs of nearly 100% of residents in 1997. By 2022, only 10% of Wailabubur's residents accessed water in naturally occurring sources while 90% accessed their water either through a Pro Air faucet in their own or a neighbor's yard, or from cisterns. More of Wailabubur's citizens have access to manufactured cisterns and the Pro Air infrastructure has lasted longer in Wailabubur than in Waiholo. By 2025, most of the utilities constructed in Waiholo had failed and use had discontinued. In Wailabubur, some residents continued receiving water through faucets in their yards. Some of these residents also had cisterns which they filled with captured rainwater and/or purchased well water.

Since the end of the 20th century, variations have emerged amongst Kodi residents, according to the results of our research and the results of research reported on the Indonesian government's BPS (*Badan Pusat Statistik*, Central Statistics Agency). Table 1 displays the main water sources used by householders at the Regency level of South West Sumba and captures how people's relationships with water have changed from 1997-2024, which is most of the period covered in our study. The number of households in SBD relying upon bore wells as their main source of water grew from 2.50% in 1997 to 40.05% in 2024 (Statistik Kesejahteraan Provinsi NTT, 1997; 2024). BPS reports that over the same 27-year period, the percentage of households who relied on rainwater and surface water (springs, rivers, lakes, ponds, irrigation) dropped from 82.20% in 1997 to 54.99% in 2024 (Statistik Kesejahteraan Provinsi NTT, 1997; 2024).

We agree with the BPS's statistics showing an increase in the availability of well water; however, the results from our own research differ from the BPS's results showing a generalized decrease in reliance on naturally occurring reservoirs. Our survey in Waiholo Village and Wailabubur Village, which are located in the area BPS refers to as a *pedesaan* (rural village) sector of South West Sumba Regency, reveal how the switch from nonanthropogenic to anthropogenic types of infrastructure is uneven and nonlinear. One explanation for the discrepancy could be the difference in the scale of the survey where the government surveyed people at the Regency scale and we

surveyed people at the village scale. Another factor could be the timing of the survey. Our survey in 2022 was administered during the Rainy Season when rainwater was available. We do not know which seasons the government surveys were conducted.

Table 1. Main Drinking Water Sources for Percentage of Households in Sumba Barat Daya

Year	Surface Water (Springs, Rivers, Lakes, Ponds, Irrigation), Rainwater, and Others	Wells (presumably hand-dug)	Bore Wells	Bottled Water and Refillable Water	Tap Water
1997*	82.20%	9.4%	2.50%	NA	5.9%
2019	86.17%	1.38%	12.26%	0.01%	0.00%
2020	77.97%	1.47%	20.13%	0.27%	0.00%
2023	71.37%	5.78%	21.57%	NA	0.00%
2024	54.99%	NA	40.05%	NA	0.00%

*Statistics for 1997 represent the entire Regency of Sumba Barat prior to its division into two Regencies of Sumba Barat and Sumba Barat Daya. [Sources: Statistik Kesejahteraan Provinsi NTT, 1997; 2019; 2020; 2023; 2024]

A compounding factor that may explain differences in the BPS figures and ours is social stratification which produces subtleties that may not be visible in Regency-scale generalizations. Access to freshwater is stratified due to individuals' and households' positionality within subgroups aligning with socioeconomic class, lineage, hamlet, household, occupation, and location of residence. Geography intersects these dimensions of identity; more specifically, proximity to roads. In both Waiholo Village and Wailabubur Village, residents who live along or near paved roads have had higher status and greater privilege with easier access to services and markets coming in and out of the interior. In the first quarter of the 21st Century, those same people are being further privileged by having easier access to piped facilities, which have been installed along paved roads and well water delivered by tanker trucks because the quality of roads impacts delivery. Living along roads signifies privilege – with differing degrees of privilege associated with differing qualities of roads – and has real consequences in further advancing the privileges of those same people. Roadside living is the cause and consequence of privilege.

Village Heads and other office holders in this part of Indonesia belong to historically upper-class lineages. These lineages tend to cluster together and to live along the sides of roads thereby leading to roadside residence being a manifestation of numerous symbolic and material forms of power. Disentangling the privileged households' symbolic power from material power and their political power from economic power is a daunting task. Similarly, separating power derived from customary structures versus the colonial and postcolonial national governmental structures is challenging. For those whose privilege is political, that type of power may either be a cause or an effect of their economic power. The more privileged households have more political and economic power. With this information, we see how Kodi society includes complexities introduced by the development of roads, tanker trucks, bore wells, manufactured cisterns, and metal pipes that influence the relationships between people and water. In sum, internal and external social hierarchies are entangled with forces introduced from encompassing regional, national, and global contexts.

6. CONCLUSION: HETEROGENOUS, NONLINEAR TRAJECTORIES

In this paper, we have described the major catchment basins in South West Sumba Regency by identifying the Pola Pare, Wai Ha, Bondo Kodi, and Kori watersheds. We have provided information about naturally occurring access points within these watersheds where residents of the Kodi subdistricts collect water. The results of our long-term ethnographic fieldwork reveal the most common sources of water for Kodi residents at the end of the first quarter of the 21st Century to be: rainfall; naturally-occurring surface water; cisterns for holding no-cost rainwater or purchased water; engineered utilities withdrawing water and channeling it to household faucets, kiosks, or public fountains; bore wells; and tanker trucks. Some of the changes benefit some people, especially those for whom accessing water is easier, whose labor output is reduced, who profit from commodified resources, who have new job opportunities, and who have more leisure time and/or the ability to diversify the use of their time, energy, and resources. These changes also have associated costs; namely, refuse, pollution, erosion, coerced out-migration, and degradation of renewable and nonrenewable resources. Even though some changes were instigated and/or welcomed by some Kodi People, problems have emerged – some unintended and unpredictable. These include problems such as unevenly distributed development, further privileging those who were already privileged, failure of engineered infrastructure, and interpersonal conflict (cf. Konradus & Dasion, 2021).

Kodi culture has transformed along multiple dimensions during the previous quarter century, and they are connected, including the linked changes between culture and water. These changes have been neither homogeneous nor uniform. Instead, their social and ecological impacts are heterogenous and nonlinear. People's reliance on naturally occurring sources versus engineered facilities for their main supplies has varied. Variations are apparent between social groups due to positionality related to their status within the existing social structure, which includes their place of residence relative to water sources and roads. Variations also have occurred over time as people have experimented with introduced water supply technologies. The number of bore wells, cisterns, and tanker delivery services has increased this century. Generally, the availability of bore wells, engineered cisterns, and water tankers for bringing water closer to people's residences is significantly changing how many Kodi people access water, and it is also changing the local political economy as water and reservoirs are commodified.

Our analysis of hydrosocial transformations thus far into the 21st Century has produced valuable lessons about the people and environment of Kodi, the costs and benefits of development, and alternative ways to interpret and manage freshwater. Many questions remain that we are eager to learn more about; including ones about the commodification of a common pool resource; emerging exchange practices; cooperation and conflict generated by novel social, political, and economic dynamics; the impacts of development and nonbiodegradable materials in the environment; the effects of extractive technologies on water quantity and quality in surface water and aquifers; and the future impacts climate change on water supplies.

The security of sufficient, higher quality water to meet humans' basic needs and simultaneously the integrity of freshwater ecosystems are major challenges considering ongoing and anticipated social changes (Konradus & Dasion, 2021) and the predicted climate changes. A better understanding of people's responses to variations in basic resources will support us as we face the future. Our documentation of hydrosocial changes connects individual experiences in Kodi with broader social and spatial contexts. A challenge with global efforts to realize access to water for all, such

as those articulated in the United Nations Sustainable Development Goals, noticed by Mehta (2016, no page number) is where "generalised, globalised arguments that underpin policy debates tend to remain disconnected from the everyday experiences of local people." We have addressed this problem by sharing deep descriptions of issues related to water at the scale of one ethnolinguistic community with the hope of contributing towards the recognition of cross-cultural patterns as they speak to the need for sustainable access to high quality water. Enormous efforts are being directed to achieving SDG 6, to "ensure access to water and sanitation for all" by 2030 (UN-Water 2023), amongst parties from around the world. We cast this deep study from Kodi into the massive stream of work being done around this aspiration.

In this paper, we have integrated information about Indonesian communities from individuals to a place-based ethnolinguistic group, to a regency, and to an island in alignment with the premise that people's interactions with water are scaled and multidimensional. Seeing freshwater in Kodi as modified by both environmental vicissitudes and cultural constructions means approaching it within its matrices of coupled social-ecological systems and contextualizing it within an ancient historical setting. The presentation of information in this article reflects this declaration: we have interwoven information about the biophysical landscape with descriptions of present-day communities.

Hydrological and social change are inherently integrated components of cultural adaptation on a highly seasonal tropical island. As agents in the multidimensional changes happening at all scales around them, Kodi People both adapt and persist. They participate in choosing what to keep, what to borrow, and what to let go. This is true in the many realms of their lives where change is afoot, including around how they think about and interact with freshwater resources in their homelands. Kodi culture is itself dynamic as evidenced by its members proactively engaging with change. When they find change works for them, they seek ways to integrate new ideas and materials into their lives which sometimes involves interpreting tangible and intangible elements into their existing social and ecological structures and other times involves constructing new meanings and practices. Kodi society is highly adaptive to the point that we might see its dynamism at once embedded within traditional ecological knowledge and catalyzing cultural sustainability. Flexibility in adjusting to ephemeral, cyclical, and permanent forms of change is a mechanism of social reproduction in Kodi culture. Resilience, in other words, is foundational to Kodi culture.

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