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Research Article

Climate Change Adaptation Strategies Utilizing Indigenous Knowledge and Food Security: An Ethnographic Study in Pariangan Village, West Sumatra

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Abstract: This study investigates how the Minangkabau community specifically in Pariangan Village adapts agricultural activities to climate variability based on traditional knowledge. This includes the utilization of religious beliefs, the interpretation of natural signs, and intergenerational informal practices. Drawing on ethnographic fieldwork involving interviews with 31 participants (each with a minimum of five years of farming experience) and supplemented by climatological data from Meteorology, Climatology, and Geophysics Agency (BMKG) in 2020–2025, this research identifies significant disruptions to seasonal patterns. Consequently, the community has developed adaptation strategies, including village granaries (*lumbung nagari*), paddy irrigation distribution systems, mixed-garden agroforestry (*parak system*), mutual cooperation (*gotong royong*), and belief-based rituals. Thematic analysis, supported by NVivo software, reveals that environmental changes are frequently interpreted through moral and cosmological frameworks. Despite the efficacy of these practices, local mechanisms remain largely disconnected from broader development frameworks. To mitigate climate variability and strengthen food security, policymakers must formalize and integrate community-based environmental knowledge into broader climate change adaptation policies and regional development planning. Simultaneously, the general public and farming communities are encouraged to adopt adaptive, climate-smart agricultural practices and actively utilize scientific weather forecasting alongside local knowledge to build long-term environmental resilience.

Keywords: Climate Change Adaptation, Local Wisdom, Minangkabau Culture, Mixed Garden Agroforestry, Paddy Irrigation, Rural Food Security.

1. INTRODUCTION

The Sustainable Development Goals, commonly abbreviated as the SDGs, are founded upon three primary pillars: the economic pillar, which aims for inclusive economic growth; the social pillar, which targets education, health, and equity; and the environmental pillar, which focuses on environmental protection, addressing climate change, and conserving natural resources. The achievement of the SDGs hinges on a delicate balance between these three fundamental pillars: environment (planet), social (people), and economy (prosperity). In reality, however, these three dimensions converge upon a single existential challenge: climate change, whose escalating impacts and unprecedented anomalies increasingly threaten socio-economic stability, rural livelihoods, and environmental sustainability [1].

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Climate change has emerged as a primary focal point of inquiry for academics worldwide, as it represents the most complex and multidimensional global challenge facing humanity today, particularly within the context of agriculture [2]. This phenomenon exerts a profound impact on global agricultural production [3], while also remaining a contentious issue in many rural communities [4]. Increasing climate variability including altered precipitation patterns, rising temperatures, and shifting wind regimes has disrupted seasonal cultivation cycles and exacerbated food insecurity across various regions [5]. These pressures directly compromise rural household resilience, particularly within smallholder and subsistence communities that depend heavily on rain-fed systems. Rural food security is inextricably linked to agricultural productivity and crop yields, both of which are increasingly vulnerable to environmental shifts, land degradation, and inadequate irrigation management [6, 7]. Furthermore, long-term projections indicate that ongoing warming, greater rainfall heterogeneity, and frequent extreme weather events will continue to undermine yields of vital staple crops such as rice [8, 9]. Amidst these escalating environmental pressures, local communities have consistently demonstrated remarkable resilience, sustaining their livelihoods even when confronted with severe climatic uncertainties [10]. Such adaptive capacity does not emerge spontaneously; rather, it is deeply anchored in Traditional Knowledge Systems and cultural practices refined across generations [11]. Consequently, researchers are increasingly investigating the dynamic interplay between climatic fluctuations and community-based adaptation strategies [12].

Perceptions of environmental change shape community response strategies by integrating observation-based knowledge with spiritual or traditional norms. In Indonesia, local knowledge remains central to how rural communities interpret and respond to climate change [13]. Farmers anticipate seasonal shifts by interpreting natural signs, including the observation of animal behavior (such as avian activity), plant phenology (e.g., flowering stages), and wind patterns. Although these interpretations are often characterized as informal, this ecological understanding is deeply integrated into agricultural practices, informing critical decisions regarding planting schedules, irrigation management, and risk mitigation [14]. The community-based climate adaptation paradigm in Pariangan Village, West Sumatra, transcends mere theoretical conceptualization; rather, it constitutes a lived manifestation of the *Alam Takambang Jadi Gur*u philosophy. This philosophical ethos guides the community in interpreting climate variability through the discernment of natural signs.

Social capital can be defined as elements within the social structure that yield beneficial outcomes for individual actors. This concept encompasses norms, networks, and trust, which enable individuals to act collectively [15]. Local wisdom in Pariangan Village functions as an effective form of social capital for hydrometeorological disaster mitigation. Here, the culture of gotong royong (mutual cooperation)—exemplified by the batobo tradition or collaborative land cultivation—serves not merely as a social activity, but as a rapid labor mobilization strategy designed to salvage harvests during impending adverse weather conditions. Regarding social structure, adherence to customary authorities (Niniak Mamak) through the mechanism of *musyawarah mufakat* (consensus-based deliberation) is pivotal in mitigating water resource conflicts during droughts. Furthermore, it ensures synchronized planting schedules to disrupt pest cycles that have intensified due to temperature shifts; thus, this ecological resilience is firmly underpinned by a collective social structure. Social capital, defined as the cohesive social norms that bind a community together, plays a critical role in shaping economic performance and fostering collective action. It encompasses shared values, a sense of responsibility, and a sense of belonging, all of which facilitate collaboration in natural resource management [16]. This heightened dependency on unpredictable natural yields creates a cascading sequence of detrimental effects. As food availability declines and economic access is constrained, households are compelled to compromise both the quality and quantity of their nutritional intake, which directly precipitates a rise in malnutrition and health vulnerabilities within these communities.

To disrupt this cycle, this study proposes a solution through the examination of adaptation strategies grounded in local wisdom. Here, local wisdom is conceptualized as a vital asset and primary resource. It encompasses the utilization of traditional knowledge, sustainable agricultural practices, customary water resource management

systems, and local food diversification to mitigate reliance on a single dietary staple.

Pariangan Village is renowned as one of the 'most beautiful villages' due to its expansive rice terraces and unique topographical configuration. Situated in Tanah Datar, West Sumatra, Pariangan offers profound traditional insights into survival amidst climate uncertainty—knowledge that has been transmitted intergenerationally exclusively through oral tradition. Despite its ecological vulnerability and heavy reliance on climate-sensitive sectors, Pariangan's success in maintaining food security remains underrepresented in academic discourse. The community relies heavily on collective social structures, Islamic traditions, and the observation of natural signs to interpret environmental flux. However, the legitimacy of this cultural framework is often overlooked within scientific contexts that tend to favor technocentric approaches Local responses to climate variability—such as discerning seasonal shifts through wind patterns or animal behavior—demonstrate a form of resilience that is deeply embedded yet remains unrecorded and uncodified in written form. To address this gap, this study aims to investigate and document community-based knowledge. By recognizing the value of epistemological pluralism, this research seeks to offer alternative solutions to environmental challenges, particularly those related to climate change. By focusing on the analysis of lived adaptation strategies practiced within the community, this study contributes to the field in several key areas. (1) It enriches the body of literature regarding local knowledge systems that remain relevant to contemporary challenges. (2) It presents practical implementation recommendations for climate adaptation planning by identifying culturally robust strategies. (3) It supports the preservation of intangible cultural heritage through the systematic codification of these practices. (4) It offers relevant insights for government policy within the national climate governance framework.

Global climate change has now become one of the most critical challenges to human survival in the 21st century. As illustrated in Figure 1, this phenomenon is no longer merely manifested in temperature anomalies; rather, it has triggered a domino effect that is simultaneously damaging environmental variables and undermining food and economic stability. In the biophysical sector, the escalation of climate change is accelerating

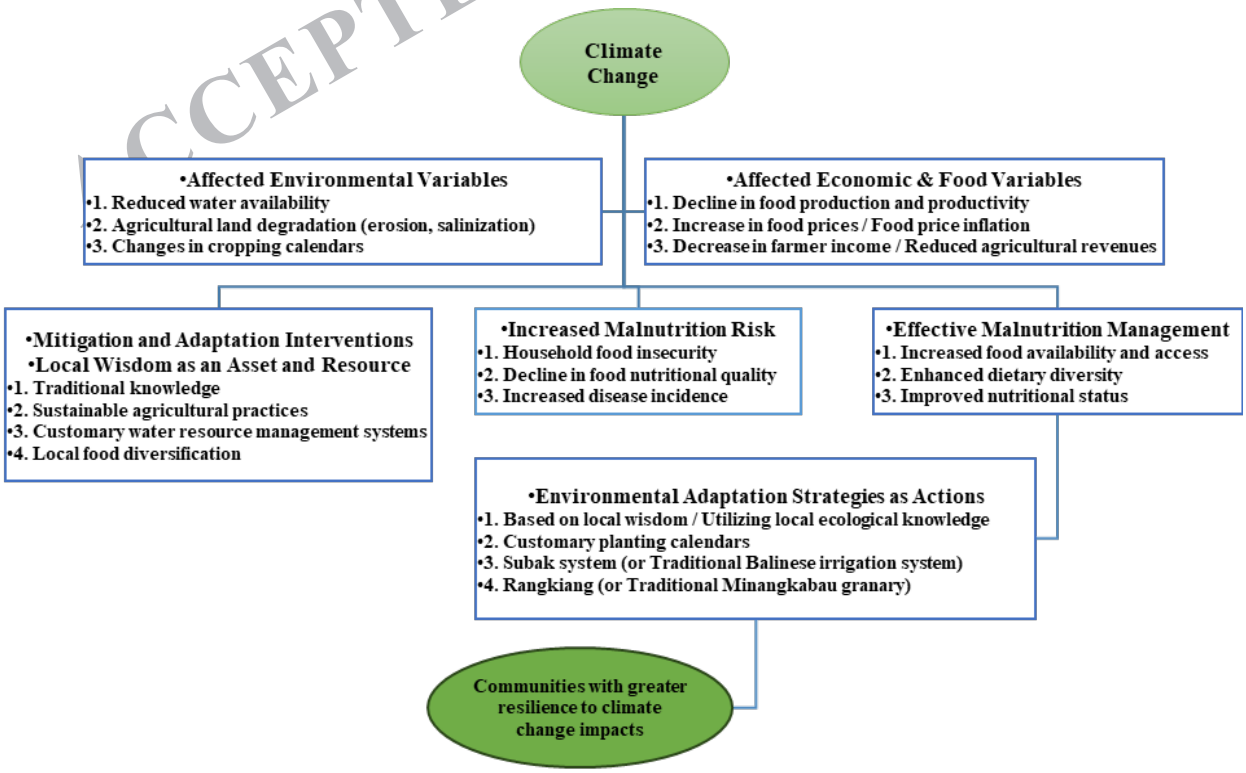

Fig. 1. Conceptual flow diagram: climate change and adaptation strategies.

the decline in the availability of clean water for irrigation, triggering land degradation due to erosion and salinization, and disrupting traditional planting calendars that have long served as a guide for the agricultural sector. Concurrently, Figure 1 details how these environmental shifts impact economic and food variables, leading to a macro-level decline in agricultural productivity, food price inflation in the market, and a drastic drop in farmers' incomes. The convergence of ecological damage and economic shocks ultimately culminates in a serious humanitarian threat, namely an "Increased Malnutrition Risk." When household-level food security is disrupted and the nutritional quality of food declines, communities—particularly vulnerable groups—become highly susceptible to various diseases.

Although, modern technological interventions are often touted as cutting-edge solutions, their implementation frequently faces obstacles in the form of high economic costs and incompatibility with local ecosystems. Amid this urgency, the utilization of local wisdom emerges as a strategic asset and potential social capital for mitigating and adapting to the impacts of climate change. According to the framework, presented in Figure 1, traditional knowledge passed down through generations has proven capable of fostering sustainable agricultural practices and equitable water management systems. In Indonesia, this community-based resilience is tangibly reflected through concrete environmental adaptation strategies. Figure 1 highlights specific traditional practices as direct actions, such as the Subak irrigation system in Bali, which ensures collective water distribution, and the *Rangkiang* food granaries in Minangkabau, which serve as social safety nets during times of famine. Through these adaptation measures rooted in local ecological knowledge, "Effective Malnutrition Management" can be achieved by enhancing food availability, dietary diversity, and nutritional status. Therefore, this study aims to analyze how the integration of environmental adaptation strategies based on local wisdom can transform vulnerable communities into societies with high resilience in the face of the dynamics of global climate change.

2. MATERIALS AND METHODS

This study employs an ethnographic approach to investigate how the community in Pariangan Village perceives and responds to climate variability. Ethnography is particularly well-suited for comprehending lived experiences, embedded knowledge systems, and social meanings [17]. The methodology employed in this study facilitates a nuanced examination of how local actors conceptualize climate change by synthesizing sensory-based knowledge, religious values, and collective intergenerational memory [18]. The research was conducted in August 2025 in Pariangan Village, West Sumatra. This site was purposively selected due to its designation as a region with Relatively High Food Security. Consequently, this scientific inquiry aims to position Pariangan as a replicable model for other regions currently grappling with climate-induced crop failures, thereby offering a framework for achieving future food security.

We collected ethnographic data through participant observation, informal and semi-structured interviews, and extensive field notes to capture seasonal cycles, communal rituals, and the diverse environmental cues utilized in daily life. Interviews were conducted with 31 participants representing diverse agricultural backgrounds. Subsequently, in-depth interviews were held with five key informants to elucidate temporal adaptation patterns during the wet and dry seasons. Among the 31 informants listed in Table 1, five were designated as key informants. These five individuals were selected purposively based on their extensive farming experience, under the premise that farmers with longer agricultural tenure have encountered more diverse climate variations and thus possess richer insights into long-term adaptation mechanisms. Data collection was conducted bilingually in Indonesian and Minangkabau; all recordings were transcribed verbatim and coded thematically. To manage the qualitative dataset, we employed thematic analysis assisted by NVivo 14 software [19]. NVivo served as a supportive tool rather than the primary analytical method facilitating the organization of the coding process, the clustering of similar data, and the identification of salient themes. These themes including the interpretation of natural signs, village granaries (*lumbung nagari*), paddy irrigation distribution systems, mixed-garden agroforestry (*parak*), and collective responses were developed based on relevant theoretical frameworks and empirical findings emerging from the data [20, 21].

Table 1. Informant profile by gender, age and occupation.

No.	Informant Code	Age (Years)	Gender	Types of plants	Farming Experience (Years)	Role in Community
1.	Informan 01	38	M	Rice	7	Millennial Farmer
2.	Informan 02	43	M	Chili Pepper	20	Farmer Group Member
3.	Informan 03	45	M	Chili Pepper	17	Independent Farmer
4.	Informan 04	40	M	Chili Pepper	15	Millennial Farmer
5.	Informan 05	61	M	Rice & Chili Pepper	40	Farmer Group Member
6.	Informan 06	52	M	Rice & Chili Pepper	30	Independent Farmer
7.	Informan 07	39	M	Chili Pepper	5	Farmer Group Leader
8.	Informan 08	37	F	Rice & Chili Pepper	11	Farmer Group Member
9.	Informan 09	60	M	Chili Pepper	20	Farmer Group Member
10.	Informan 10	56	F	Rice & Chili Pepper	20	Independent Farmer
11.	Informan 11	63	M	Vegetables	5	Farmer Group Member
12.	Informan 12	58	F	Rice & Onions	30	Independent Farmer
13.	Informan 13	48	F	Rice	3	Farmer Group Leader
14.	Informan 14	65	M	Onions	35	Independent Farmer
15.	Informan 15	51	M	Onions	10	Independent Farmer
16.	Informan 16	53	F	Vegetables & Maize	15	Independent Farmer
17.	Informan 17	63	M	Vegetables	10	Farmer Group Member
18.	Informan 18	48	F	Rice & Vegetables	15	Independent Farmer
19.	Informan 19	50	F	Rice	10	Independent Farmer
20.	Informan 20	44	F	Rice	5	Farmer Group Member
21.	Informan 21	29	F	Vegetables	5	Farmer Group Member
22.	Informan 22	45	F	Vegetables	5	Vice Chairperson
23.	Informan 23	45	F	Onions	3	Independent Farmer
24.	Informan 24	46	M	Onions & Rice	25	Farmer Group Leader
25.	Informan 25	66	M	Rice	10	Independent Farmer
26.	Informan 26	55	F	Vegetables	15	Farmer Group Member
27.	Informan 27	48	F	Rice	10	Farmer Group Member
28.	Informan 28	53	M	Onions	20	Farmer Group Member
29.	Informan 29	49	M	Chili Pepper & Vegetables	20	Farmer Group Member
30.	Informan 30	39	F	Chili Pepper & Vegetables	21	Farmer Group Member
31	Informan 31	63	F	Rice & Chili Pepper	25	Nagari Group Leader

To complement the in-depth ethnographic insights, this study integrates secondary climate data from the Meteorology, Climatology, and Geophysics Agency (BMKG) Minangkabau-Padang Pariaman Meteorological Station (https://www.bmkg.go.id/). Monthly and annual meteorological data (2020–2025)—encompassing rainfall (mm), average temperature (°C), wind speed (m/s), and solar radiation (kJ/m²/day)—were utilized to analyze relevant seasonal and interannual climate trends. The wet season (November–April) and dry season (May–October) were delineated according to the Meteorology, Climatology, and Geophysics Agency (BMKG) climatological classification [22]. Data triangulation was achieved by synthesizing primary ethnographic data with secondary meteorological records. This multi-source approach bolsters the validity of the findings by capturing both the emic (local internal understanding) and etic (external scientific data) dimensions of environmental comprehension.

Based on the Table 1, the sample selection in this study used a purposive sampling method with specific inclusion criteria, primarily targeting farmers who have actively managed agricultural land for an extended period, with the majority meeting the baseline threshold of at least five years of farming experience. This time limit was deliberately set because it is considered a critical threshold at which a farmer has experienced extreme climate variability, including "reverse season" phenomena (such as wet droughts caused by La Niña or prolonged droughts caused by El Niño). Empirical experience spanning at least half a decade ensures that informants possess

not only theoretical knowledge but also practical adaptation strategies, crop failure risk mitigation, and accumulated local ecological knowledge in responding to environmental uncertainty. Thus, the selected sample represents information-rich cases capable of providing in-depth data on temporal adaptation patterns in the study area.

3. RESULTS AND DISCUSSION

3.1. Local of Perceptions of Climate Variability

In an era where climate change has emerged as a paramount concern for agricultural development, there is a pressing need to identify various climate-smart practices as adaptation measures [23]. Climate-smart practices encompass land and water management strategies that possess the potential to build resilience to climate change [24]. The community of Pariangan Village conceptualizes and defines climate change not through standard scientific terminology, but rather through the observation of tangible disruptions or alterations in the regularity of seasonal patterns. Intergenerationally, the community has relied upon stable and predictable environmental signs to determine the agricultural calendar, encompassing land preparation, planting, cultivation maintenance, harvesting, and re-planting preparations. However, over the past decade, these patterns have become increasingly erratic. The Pariangan community frequently refers to this phenomenon using vernacular terms such as *'musim terbalik*' (inverted seasons) and 'cuaca tidak menentu' (erratic weather). This heightened uncertainty in seasonal periodicity has precipitated detrimental effects on agricultural productivity. These findings regarding community perceptions, derived from primary data, are corroborated by secondary climatological data from Meteorology, Climatology, and Geophysics Agency (BMKG) in 2020–2025.

As evidenced by the meteorological data presented in Figure 2, the average monthly rainfall in Pariangan, the study area, exhibits high climate dynamics. More specifically, Figure 2 highlights the severe climate volatility experienced by the local farmers, contrasting the intense El Niño drought in September 2023 (where rainfall dropped to just 52 mm) with the heavy La Niña wet anomaly in April 2024 (reaching 374 mm). These sharp contrasts confirm that informants with at least 5 years of experience have practically navigated through these extreme shifts, ensuring the reliability of their accumulated local ecological knowledge in adapting to climate uncertainty.

The monthly mean rainfall patterns across the three monitoring stations (Batipuh, Galo Gadang, and Cubadak) from 2021 to 2025 are illustrated in Figure 2. Overall, all three stations exhibit a typical bimodal (equatorial) rainfall distribution characterized by two distinct wet peaks and a pronounced dry dip. The primary troughs across all locations were for Galo Gadang (88 mm), followed by Cubadak (105 mm) and Batipuh (133 mm). Distinct spatial variations are evident in the timing and magnitude of maximum rainfall. Batipuh consistenly experiences higher precipitation throughout the year (annual average 2.454 mm), with an intense late-year peak in November (291 mm) and December (305 mm), as well as secondary peaks in April (232 mm) and September (225 mm). In contrast, Cubadak exhibits its highest rainfall during the first transition period in March (237 mm) and April (222 mm), before stabilizing around 205 mm in November–December. Galo Gandang displays a more subdued precipitation profile (annual average ~1,899 mm), peaking moderately in March and November (both at 205 mm). These intra-regional discrepancies reflect local microclimatic and orographic influences across the catchment area, which are essential for understanding local hydrological dynamics and water availability.

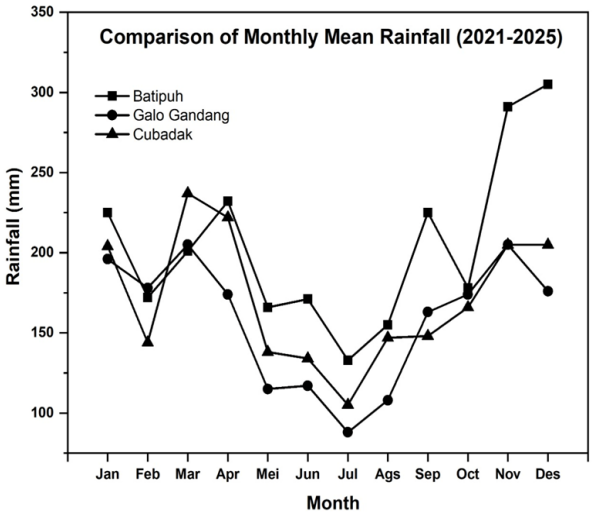

Fig. 2. Comparison of monthly mean rainfall (2021–2025) across Batipuh, Galo Gandang, and Cubadak rainfall stations.

Due to the absence of a rainfall observation station within Pariangan Village, precipitation characteristics were analyzed using records from the three nearest surrounding stations: Batipuh, Galo Gandang, and Cubadak. Figure 2 presents the comparison of the 5-year monthly mean rainfall calculated over the period 2021–2025 across these three stations.

3.2. Indigenous Wisdom of Pariangan

Indonesia is renowned for its cultural diversity. This cultural heterogeneity stems from various ethnic groups disseminated throughout the archipelago. Culture itself constitutes the distinguishing characteristics and collective knowledge possessed by a particular societal group [25]. Minangkabau culture stands as one of the oldest cultural heterogeneities in Indonesia. It originated from the Minangkabau people, who primarily inhabit West Sumatra and its surrounding regions. The existence of Minangkabau culture remains observable today, both directly and indirectly [26, 27]. This central region is designated as the darek (the core/interior) region that serves as the source of law, custom (adat), and social order for all members of the Minangkabau society. The darek is further subdivided into three territories known as Luhak Nan Tigo. The three Luhak Nan Tigo territories are Luhak Tanah Datar, Luhak Agam, and Luhak Limapuluh Kota.

Pariangan Nagari, situated within Tanah Datar Regency, West Sumatra, is frequently cited as an ancestral settlement or one of the oldest traditional administrative units in the Minangkabau domain, moreover, several oral traditions deem it the progenitor point (or genesis) of the Minangkabau civilization [28]. The local wisdom practices of Pariangan, such as the Communal Granary System (Lumbung Nagari) and the Mixed Homegarden Agroforestry System (Parak), are not isolated agricultural techniques; they are codified adaptations enforced and validated by the Darek socio-legal structure. The adat system originating from this core region provides the normative basis for collective action, ensuring that strategies like equitable irrigation distribution and the maintenance of food buffer stocks are followed, even when resource scarcity intensifies due to climate variability. Pariangan's status as an ancestral center ensures the preservation of long-term ecological knowledge that can inform contemporary adaptation strategies, providing historical context for handling extreme weather events or shifts in phenological cycles. The wisdom of Pariangan—rooted in the foundational and authoritative Darek structure—is the institutional and knowledge bedrock that transforms practical ecological techniques into effective, enforced, and sustainable regional climate resilience strategies. Knowledge is inherently contextual; therefore, it is imperative not merely to acknowledge this, but also to integrate and elaborate upon its underlying context [29]. The intrinsic significance of indigenous knowledge is only graspable through direct engagement with the community [30].

The operationalization of this indigenous wisdom is centrally manifested in the Rumah Gadang. This structure is not merely a residence but serves as the institutional nexus for collective action, possessing a dual adaptive function. Architecturally, its stilt foundation and sharply curved gonjong roof represent codified physical adaptations against hydrological extremes (flooding and intense rainfall) inherent to the region. Institutionally, the Rumah Gadang functions as the primary communal locus where resource governance decisions—critical for long-term climate resilience—are formalized under adat. These decisions include the equitable distribution of irrigation water and the systematic management of the Lumbung Nagari (communal granary). In the architectural configuration of the Rumah Gadang, the traditional Minangkabau house is not designed as a solitary entity; rather, it serves as the focal point of a surrounding building complex. A primary ancillary structure within this ensemble is the Rangkiang, which functions as a rice granary. This centralization of decision-making ensures the necessary social cohesion and communal adherence required for the effective and sustainable implementation of these regional adaptation strategies. In Pariangan itself, the existence of the traditional house can be seen in the picture below:

As illustrated in Figure 3 the spatial distribution identifies approximately 24 well-preserved Rumah Gadang structures whose structural existence remains actively maintained. This high density of traditional architecture reflects the profound commitment of the Pariangan community to cultural preservation. Rather than serving as mere

Fig. 3. Image of the Rumah Gadang distribution in Pariangan.

historical artifacts, these preserved ancestral houses function as a socio-ecological backbone that actively sustains and reinforces the community's daily socio-cultural and communal life.

3.3. Communal Granary System (*Rangkiang*)

Minangkabau culture, centered in West Sumatra, possesses a distinct social structure and philosophical ethos that serve as the foundation for its various customary (*adat*) institutions. Within this framework, the autonomous socio-political unit is known as the Nagari. A Nagari constitutes more than a mere administrative territory; rather, it is a customary law community unit governed by customary leaders, or Niniak Mamak. It is within this structural order that the concept of the Lumbung Nagari (*Rangkiang*) emerged and evolved. The Lumbung Nagari transcends its function as a mere physical structure for rice storage; it represents a socio-economic institution that embodies local wisdom regarding risk management and food security. The presence of a fully stocked granary serves as a symbol of a Nagari's prosperity, dignity, and preparedness in facing an uncertain future. Historically, the primary function of the Lumbung Nagari has been to operate as a social safety net and a fundamental pillar of community food resilience. Its role becomes particularly vital when confronting unpredictable seasonal cycles. In alignment with this context, the study by Fakhriati *et al*. [31] posits that a pivotal long-term strategy employed by rural communities is the extended storage of rice within traditional granaries. This mechanism enables them to regulate market prices, avert food scarcity, and insulate themselves against economic fluctuations induced by environmental changes.

The *Rangkiang* in Minangkabau culture serves multifaceted functions, which are distinguished by its varied architectural variations and spatial layout. Morphologically, the Rangkiang aligns with the architectural style of the Rumah Gadang. It features a gonjong (horn-like) roof constructed from sugar palm fiber (ijuk), with supporting pillars elevated to a height proportionate to those of the Rumah Gadang. Generally, there are four types of Rangkiang categorized based on their function and form, wherein the quantity serves as an indicator of a clan's economic status. These four types are:

Based on Table 2, the traditional institution of *Rangkiang* in the Minangkabau culture functions as a sophisticated, multi-tiered community food security system rather than a simple storage facility. The structural diversification of *Rangkiang* reflects

Table 2. Type and functions of Rangkiang.

Types of Rangkiang	Functions of Rangkiang
Si Tinjau Lauik	This variant is specifically designated for storing paddy allocated as a medium of exchange to acquire necessities that cannot be produced independently.
Si Bayau-Bayau	Its function is allocated as a repository for rice stocks intended to meet daily subsistence needs.
Si Tangguang Lapa	This structure serves as a repository for emergency rice reserves, specifically designated for utilization during famine or periods of scarcity.
Rangkiang Kaciak	Its function is highly specific: the storage of padi abuan. This rice stock is allocated as seed for planting and as working capital for the subsequent cultivation cycle.

an advanced strategy for ecological risk mitigation and resource management. Specifically, *Si Tinjau Lauik* serves an economic liquidity function by storing paddy allocated for external trade and securing goods that cannot be produced locally. For immediate food security, *Si Bayau-Bayau* functions as the baseline safety net, safeguarding the repository for daily household subsistence needs. To cushion the community against severe environmental shocks, *Si Tangguang Lapa* is designated as a critical emergency reserve, deployed exclusively during famines, crop failures, or prolonged periods of scarcity. Finally, agricultural sustainability and long-term capital preservation are maintained through *Rangkiang Kaciak*, which isolates *padi abuan* (sacred seed stocks) to secure high-quality seeds and working capital for the subsequent cultivation cycles. Consequently, the matrix in Table 2 demonstrates how traditional architectural forms embody dynamic institutional adaptation strategies to maintain community resilience in the face of environmental uncertainty.

3.4. Traditional Rice Field Irrigation Distribution System

For indigenous communities, adaptation is conceptualized not as an abstract abstraction or a novel reaction solely to climate change, but rather as a continuous practice deeply rooted in socio-political and cultural contexts spanning millennia. Adaptation is thus constructed as the application of old ways for new days; wherein ancestral survival strategies are repurposed to address contemporary challenges [32]. The traditional paddy irrigation distribution system in Nagari Pariangan constitutes a manifestation of local wisdom that integrates hydrological techniques with socio-communal values in natural resource management. Within the terraced agrarian landscape on the slopes of Mount Marapi, water is perceived not as private property, but as a common-pool resource whose management is grounded in principles of equity and fair distribution. The mechanism of water distribution is executed through the Tali Banda network, flowing via gravity from upstream to downstream, wherein water allocation is regulated proportionally using a rotational system known as *gilir ganti*, particularly during periods of diminished discharge in the dry season. This governance is strictly overseen by customary institutions led by a *Kapalo Banda*, functioning to ensure equitable access and resolve potential conflicts among farmers through deliberation (*musyawarah*). The sustainability of this system is further bolstered by the tradition of mutual cooperation, or manambak banda, in the physical maintenance of irrigation channels prior to the planting season, which collectively guarantees water supply availability for crop yield stability and local food security.

3.5. The parak Mixed-Garden Agroforestry System Post-Agricultural Sycle

The Parak agroforestry mixed-garden system constitutes a vital practice of local wisdom in Pariangan, functioning as an ecological and economic buffer, particularly subsequent to the conclusion of the primary rice cultivation cycle. Characterized by polyculture and stratified planting on dry land, the parak system strategically provides dietary diversification and sustainable income sources for households outside the annual rice harvest periods, thereby mitigating total reliance on staple food stocks and safeguarding economic stability. The paramount function of parak in the post-harvest context is its role in ecological conservation: through the maintenance of continuous vegetative cover, the system is highly effective in preventing soil erosion caused by high-

intensity rainfall—a significant hazard in the hilly terrain of Tanah Datar. Consequently, the parak system represents an essential adaptation strategy; it not only ensures food security through sustainable yields but also stabilizes soil conditions, serving as an ecological bulwark against the variability and disaster risks associated with climate change. In alignment with these findings [33] research elucidates that Pariangan constitutes a village characterized by a rich cultural landscape, owing to its possession of comprehensive life-sustaining elements. Most notably, the proportional availability of mixed gardens serves as a critical component in bolstering food security within this context. The local knowledge held by the Pariangan community regarding the utilization of natural resources—specifically plant biodiversity—represents a cultural asset that necessitates rigorous investigation to ensure that traditional utilization practices are preserved from extinction. Currently, a significant portion of local ethno-botanical knowledge is being eroded by dynamic environmental shifts, often disappearing without having been adequately reviewed or systematically documente [34]. In line with this, research conducted by Kakati [35] underscores the significance of agroforestry practices for indigenous communities.

3.6. Integrating Ethnographic findings with Climatic Variables

Indigenous knowledge, as articulated in research literature, possesses the developmental potential to influence the sustainability of rural livelihoods across multiple development sectors. One emerging domain for its global application is the field of climate variability and climate change [36]. The synthesis of climatological data and ethnographic findings elucidates how climate variability is constructed and responded to at the local level. Rainfall data from Meteorology, Climatology, and Geophysics Agency (BMKG) Minangkabau (2020–2025) confirms the presence of tangible fluctuations that correlate with farmers' narratives regarding harvest uncertainty. However, the ethnographic perspective reveals that these weather anomalies are not merely perceived as environmental phenomena; rather, they are interpreted through spiritual and social lenses—for instance, as a Divine trial. Consequently, effective climate adaptation frameworks must transcend technical vulnerability analyses by integrating the moral, emotional, and cultural dimensions that underpin community resilience. Given the structural and contextual socio-economic issues that constrain access or exacerbate community food insecurity, an examination of inter-organizational collaboration would enhance both scientific understanding and applied practice [37].

3.7. Employing the Theoretical Frameworks of Resilience and Traditional Ecological Knowledge

Within the context of agrarian societies, subsistence farming frequently constitutes a form of 'silent sustainability' or 'unintentional sustainability practice.' Farmers' motivations are primarily driven by the desire to secure healthy food and adhere to family traditions, rather than solely by global environmental discourse; nevertheless, the outcome contributes significantly to ecological balance [38]. These findings corroborate the validity of socio-ecological resilience theory, particularly regarding the dimensions of flexibility, social learning, and cross-scale adaptation. In Pariangan, the community's adaptive capacity is not merely manifested in physical infrastructure but is also deeply embedded within social and cultural capital. Specifically, the Rangkiang (rice granary) transcends its architectural function; it represents a form of 'social infrastructure' that ensures communal food security during crises. This serves as a crucial buffer mechanism that is frequently overlooked by state-led climate adaptation programs, which tend to be technocratic and top-down in nature. Furthermore, the success of local adaptation is profoundly shaped by Traditional Ecological Knowledge (TEK) [39]. The explicit articulation of knowledge, evolved through years of experience and learning, is critical to document and disseminate [40]. The community's capacity to interpret natural phenomena aligns with the Minangkabau philosophical aphorism, "*Alam Takambang Jadi Guru*" (Nature Unfurled Becomes a Teacher).

The Minangkabau philosophy of 'Alam Takambang Jadi Guru' serves, fundamentally, as a manifestation of an empirical knowledge system that positions the natural world as an open-air laboratory and the most authentic source of truth. Viewed through the lens of Traditional Ecological Knowledge (TEK), this aphorism transcends mere poetic expression; rather, it operates as a scientific

methodology grounded in longitudinal observation. This ethos cultivates an acute sensitivity within the community toward the regularity of natural patterns. Consequently, climate adaptation in Pariangan is revealed to be a hybrid process: a synergy between institutional memory (embodied in rituals and traditions) and ecological literacy regarding evolving natural signs. In the context of climate change, nature 'instructs' humanity through deviations from established regularities. Humans, acting as students, are thus mandated to decipher these signs meticulously through sensory perception and intergenerational collective experience.

4. CONCLUSIONS

This study concludes that climate adaptation in Pariangan transcends a mere technical response to weather shifts; rather, it constitutes a dynamic process constructed through the dialectic between Traditional Ecological Knowledge (TEK) and social cohesion. By employing methodological triangulation that integrates rainfall data, ethnographic observation, and NVivo-assisted thematic analysis, this research elucidates that community resilience is inherently endogenous—cultivated from within rather than imported from external sources. Our findings challenge the hegemony of technocratic, top-down adaptation models. Conversely, the Pariangan community leverages its own 'cultural technologies' terraced irrigation systems that mitigate erosion, the parak mixed-garden agroforestry system, gotong royong traditions that distribute labor burdens, and the revitalization of the rangkiang function as an economic buffer during periods of scarcity. While centered on a specific case study in Pariangan, this research offers a critical blueprint for future comparative studies across agrarian rural Indonesia. The primary implication is unequivocal: sustainable climate policy must shift from a purely technical orientation toward an ethical and inclusive approach, wherein local wisdom is no longer viewed as a relic of the past, but as a vital asset for future resilience strategy.

5. POLICY IMPLICATIONS AND COMMUNITY SOLUTIONS

Food security remains a critical concern for nations worldwide. Despite the implementation of numerous programs and projects dedicated to this issue, millions of individuals globally continue to experience food insecurity, a significant proportion of whom reside in developing countries. Because the challenge of food security is inherently multi-sectoral, cross-sectoral, and interdisciplinary, addressing it necessitates the sustained participation of actors from diverse sectors collaborating across institutional scales. To address the escalating challenges of the climate crisis, we recommend a fundamental policy reformulation that integrates ethnographic findings with local aspirations, particularly in West Sumatra. State policies that rely exclusively on technocentric approaches, such as Indonesia's ProIklim, require recalibration: shifting from rigid technical metrics toward adaptive programs that institutionalize local wisdom-based solutions. Employing the theoretical frameworks of Resilience and Traditional Ecological Knowledge (TEK), policymakers should formally adopt and support time-tested community mechanisms as core pillars of agrarian and climate policy. Concretely, the revitalization of the Rangkiang (communal granary) function must be positioned not merely as an act of cultural preservation, but rather as an institutionalized communal food security and risk-buffering mechanism during ecological and economic crises. Furthermore, this initiative must be coupled with state support for traditional rice field irrigation distribution systems, harmonizing physical infrastructure with customary water-sharing norms and gender-responsive participatory governance. The equitable engagement of both men and women in water governance is crucial, given their distinct water usage patterns for agricultural and domestic purposes that are frequently overlooked in conventional planning, thereby not only ameliorating physical infrastructure but also fostering inclusive resource management and mitigating resource conflicts. Finally, agricultural and climate strategies should actively incentivize the parak mixed-garden agroforestry system in the post-agricultural cycle. Rooted in TEK, the multi-layered vegetative structure and crop diversity of the parak landscape enhance ecological resilience through soil conservation and biodiversity preservation, while providing economic buffering against market volatility and crop failures. By embedding these indigenous systems—Rangkiang, traditional irrigation governance, and parak agroforestry—into overarching policy frameworks, policymakers can achieve more inclusive, socially grounded, and climate-resilient food security governance.

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7. ETHICAL STATEMENT

The research protocol adhered to the ethical guidelines for social science research.

8. CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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10. AUTHORSHIP CONTRIBUTION STATEMENT

Dewi Rahmadani Siregar: Conceptualization, Data collection, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing-original draft, Writing-review and editing. Eri Barlian: Supervision, Writing-review & editing. Abdul Razak: Supervision, Writing-review and editing; Ikmanisa Khairati: Data collection, Investigation; Defiani Dwiyanti: Writing – review and editing.

11. DECLARATION

The authors declare that the results of this manuscript are original, unpublished, and not under consideration elsewhere. Approval from all authors has been secured. Upon acceptance, the copyright will be assigned to the Pakistan Academy of Sciences, and all necessary permissions for third-party copyrighted materials have been obtained to ensure no infringement. The authors acknowledge the use of Grammarly and automated English enhancement tools to refine the linguistic structure and clarity of this manuscript. However, the use of these technologies was strictly limited to language editing. All data collection, analysis, findings, and discussions presented herein are entirely original and were conceptualized and executed solely by the authors.

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