鹿児島大学
国際島嶼教育研究センター
International Center for Island Studies, Kagoshima University

Institution for Marine & Island Cultures

PROGRAM BOOK

The 13th East Asian Island and Ocean Forum (EAIOF)

Theme:
Archipelagic Sustainability and Rediscovering the Future Value of Island Regions

Ambon, November 23 - 24, 2026



Foreword



Prof. Dr. Ir. Wardis Girsang, M.Si., Ph.D.
Chairperson, EAIOF 2026
Professor in Rural Systems Management, Faculty of Agriculture, Pattimura University

Distinguished Guests, Keynote Speakers, Respected Delegates, and Fellow Scholars,

Tabea and a very warm welcome to Ambon!

On behalf of the Organizing Committee, it is my distinct honor to welcome approximately 100 participants and esteemed delegates to The 13th East Asian Island and Ocean Forum (EAIOF 2026) at Hotel Zest, Ambon. Historically celebrated as the epicenter of the global 'Spice Islands,' Ambon today serves as an extraordinary living laboratory where centuries of customary maritime wisdom meet cutting-edge archipelagic science and ocean governance.

Our forum proudly gathers 38 paper presenters representing leading universities and research organizations across South Korea, Taiwan, Japan, China, the Philippines, and Indonesia—including scholars from Universitas Pattimura, IAKN Ambon, and Konservasi Indonesia. Together, we convene to redefine islands not as isolated peripheries, but as vital hubs of Blue Economy innovation, ecological stewardship, and regional connectivity.

Our commitment to archipelagic sustainability builds upon a continuous academic story. Having served as Chairperson of the Organizing Committee for the 19th Indonesian Regional Science Association (IRSA) International Conference held in Ambon in July 2024—which examined climate change and gender inequality in island regions—I have witnessed how localized ecological wisdom illuminates global solutions. EAIOF 2026 carries this narrative forward by broadening our interdisciplinary collaboration across East and Southeast Asia.

Over these two days, EAIOF 2026 provides a dynamic academic platform to exchange rich experiences, disseminate groundbreaking research findings, and debate pressing challenges—from Blue Carbon initiatives and Dusung agroforestry to maritime digitalization and small-island food security.

A Guiding Principle for Our Deliberations:

"Take full advantage of this Forum to exchange rich experiences, disseminate research findings, and engage in active discussions. If you do not understand, ask; and if you do understand, ask even more!"

An international gathering of this magnitude is made possible only through generous institutional backing, essential financial support, and dedicated teamwork. On behalf of the committee, I extend our deepest gratitude to:

- Rector of Pattimura University: Prof. Dr. Fredy Leiwakabessy, M.Pd., for his visionary leadership and essential financial support in funding this international forum.
- LPPM Unpatti & Archipelagic Center of Excellence: The Head of the Research and Community Service Institute (LPPM) for steadfast administrative and institutional stewardship.
- Deans of Collaborating Faculties: The Deans of Medicine, Agriculture, Social and Political Sciences (FISIP), Teacher Training and Education (FKIP), Law, Postgraduate Studies, Engineering, and Science & Technology for their unified interdisciplinary backing.
- Founding Partner Institutions: Mokpo National University (Founder Prof. Sun-Kee Hong) and Kagoshima University for their enduring co-organizing partnership

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Welcoming Remarks from the Rector of Pattimura University



Prof. Fredy Leiwakabessy, M.Pd.

Rector of Pattimura University

Distinguished Guests, Keynote Speakers, Respected Delegates, and Fellow Scholars,

Tabea and a very warm welcome to Ambon!

On behalf of the entire academic community of Pattimura University, it is my distinct honor and privilege to welcome approximately 100 participants and distinguished scholars to The 13th East Asian Island and Ocean Forum (EAIOF 2026) at Hotel Zest, Ambon. We take immense pride in hosting this prestigious international forum in Maluku—a region historically celebrated as the world's "Spice Islands" and today flourishing as an extraordinary living laboratory for archipelagic sustainability, marine stewardship, and climate-resilient ocean governance.

At this very moment, Pattimura University is achieving an extraordinary academic milestone by hosting two major high-level events concurrently: the National Archipelagic Universities Consortium alongside the 13th East Asian Island and Ocean Forum (EAIOF 2026). Uniting national archipelagic university leaders and international ocean scholars in Ambon creates a powerful synergy. Together, these dual events decisively reinforce our institutional identity as an archipelagic university that delivers tangible, real-world impact for regional governments across island territories.

This historic convergence directly propels our overarching institutional vision and mission: "Shining Toward a World-Class University" (Bersinar Menuju Universitas Kelas Dunia). By anchoring global academic discourse in local archipelagic realities, Pattimura University demonstrates that small-island universities can lead global conversations on climate resilience, Blue Economy innovation, and sustainable marine governance.

For generations, island and coastal territories across East and Southeast Asia were often perceived through a narrow lens of geographic isolation, environmental vulnerability, and economic fragmentation. However, as the Rector of an archipelagic university rooted in a province of over 1,400 islands, I champion a fundamentally different narrative. Archipelagos are not remote peripheries; they are dynamic, interconnected centers of ecological stewardship, Blue Economy potential, and customary wisdom.

Pattimura University—through our Archipelagic Center of Excellence (LPPM), the Faculty of Agriculture, and our interdisciplinary faculties—is steadfastly dedicated to advancing small-island science. Through our enduring co-organizing partnerships with Mokpo National University (led by Founder Prof. Sun-Kee Hong) and Kagoshima University, EAIOF 2026 convenes 37 paper presenters representing premier universities and research organizations across South Korea, Taiwan, Japan, China, the Philippines, and Indonesia—including scholars from Pattimura University, IAKN Ambon, and Konservasi Indonesia.

Over these two days, EAIOF 2026 provides a timely multidisciplinary platform to address pressing regional imperatives: from Blue Carbon initiatives and traditional Dusung agroforestry to maritime digitalization via "Hub and Spoke" models, coastal hazard mitigation, and small-island food security.

An international gathering of this magnitude succeeds through collaborative commitment. On behalf of the university, I extend my sincere appreciation to the Board of Advisors, the Steering Committee, the Organizing Committee chaired by Prof. Wardis Girsang, our collaborating Deans, the

Head of LPPM, and our strategic financial partners—Bank Indonesia (BI) and Bank Tabungan Negara (BTN)—for their unwavering support.

Beyond our intensive academic sessions, we warmly invite you to experience the authentic hospitality of Ambon, the "City of Music," and enjoy our rich culinary and cultural heritage. May EAIOF 2026 spark transformative solutions, enduring academic networks, and a shared commitment to a sustainable future for our oceans and archipelagos

Tabea, and welcome to Ambon!

Organizing committee

Board of Advisors

Prof. Fredy Leiwakabessy, Rector of Pattimura University
Prof. Sun-Kee HONG, Mokpo National University (The Founder of EAIOF)
Prof. August E. Pattiselanno, Dean, Faculty of Agriculture Pattimura University
Prof. Yasushi Otsuka, International Center for Island Studies, Kagoshima University

Steering Committee:

Prof. Dominggus Malle, Vice Rector for Academic A ff airs, Pattimura University
Dr. Ruslan H.S. Tawari, Vice Rector for Planning, Cooperation, and Information Systems
Dr. Estevan Huliselan, Head of the Research and Community Service Institute, Pattimura University
Prof. Sota Yamamoto, International Center for Island Studies, Kagoshima University
Prof. Natelda R.Timisela, Head of the Department of Agricultural Socio-Economics

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Venue and logistics

Dr. Paulus Melkianus Puttileihalat, S.P., M.Si.

Expo and Poster

Weldemina Batseba Parera, S.P., M.P.

Rundown

Day 1 – Monday, 23 November 2026

08:00–09:00	Participant Registration
09:00–09:05	Opening Ceremony & National Anthem (Indonesia Raya)
09:05–09:10	Prayer
09:10–09:15	Report by the Chair of Organizing Committee
09:15–09:25	Welcome Address & Official Opening by Rector of Pattimura University
09:25–09:55	Keynote Address - Mod: **Wardis Girsang** Sustaining Islandness through Resilience: Eco-Cultural Diversity and Socio-Ecological Transition in Island Communities - **Sun-Kee Hong**
09:55–10:10	Keynote Q&A Session - Mod: Wardis Girsang
10:10–10:40	Coffee / Morning Snack Break & Cooperation Discussion: Opportunities for Academic Collaboration, Research Partnerships, and Institutional Cooperation
10:40–11:10	Plenary Session 1 - Mod: **Simon H. T. Raharjo** Agroforestry (*dusung*) in Ambon Island, Indonesia: Relationship between slope gradient and tree species within four plots - **Sota Yamamoto, et al.** Navigating Sustainability: Island Cultures and Multivocal Conservation in Maluku - **Hermien L. Soselisa**
11:10–11:25	Q&A Session (Plenary 1) - Mod: Simon H. T. Raharjo
11:25–12:15	Plenary Session 2 - Mod: **J. Audrey Leatemia** Maritime Archaeology and the Archipelagic Character of the Ryukyus: A Historiography - **Hidekazu Sensui** Nature-based Solutions for Land Use and Climate Change in Islands and Coastal Areas: A Case Study of Shinan and Muan - **Jae-Eun Kim** GIS-Based Spatial Assessment of Coastal Vulnerability to Multiple Hazards: Evidence from Ambon Island - **Ferad Puturuhu & Enrico R. Matitaputty** Rethinking Island Agriculture: The Role of Agricultural Product Technology in Building Resilient and Sustainable Food Systems - **Helen C. D. Tuhumury, et al** Can Maluku's Traditional Foods Modulate Microbiome Function and AMR Pathogen Virulence? Exploring Island Food Resources for Sustainable Health - **Astri D. Tagueha, et al.**
12:15–12:30	Q&A Session (Plenary 2) - Mod: J. Audrey Leatemia
12:30–13:30	Lunch Break
13:30–14:20	Plenary Session 3 - Mod: **Astri D. Tagueha** Climate Resilience Based on Traditional Knowledge in the *Gudeuljang* Rice Terraces of *Cheongsando* - **Gyeong-Ah Lee** From Rock to Sand: AI-Based Cultural Translation of the Mountain–River–Sea Material Genealogy in the Shuangxi–Fulong Region, Taiwan. - **Yu-Li Chuang** Where Ecological Value Meets Customary Tenure: Rationale and Socio-spatial Considerations for Zoning the Banda Sea Large-Scale Marine Protected Area, Maluku, Indonesia. - **Yudi Herdiana, et al.** Embedded Instrumentation for Sustainable Infrastructure Development in Archipelagic Regions: A Preliminary Rock Assessment Approach. - **Ronaldo Talapessy, et al.** Customary Institutions and the Governance of Mangrove Commons: Lessons from Maluku, Indonesia. - **Wiesye V. Pelupessy & Pieter Th. Berhitu**

14:20–14:35	Q&A Session (Plenary 3) - Mod: Astri D. Tagueha
14:35–15:15	Plenary Session 4 - Mod: **Yolanda Apituley** Balancing Tradition and Ecology: Changes in Protected Marine Species and Associated Organism Groups Before and After *Sasi* in Maluku. - **BG Hutubessy, et al.** Ritual Communication within the Cultural Space of the Maluku Islands Society in The Digital Era. - **Dortje L. J. Lopulalan & Beatriz Bridget Tanasale** From Data to Decisions: Real-World Applications of AI for Sustainable Archipelagic Development. - **Wilma Latuny** Integrating Local Resources through Green Tourism: A Resource-based Community Resilience Model for Offshore Island Revitalization. - **Shyi-Liang Yu & Ying-Chien Chu**
15:15–15:30	Q&A Session (Plenary 4) - Mod: Yolanda Apituley
15:30–15.45	BI Presentation
15.45–16:00	Afternoon Snack Break & Wrap-up Day 1
16:00–18:00	Preparation & Transport to Mayor's Office (Pick-up from Santika & Zest Hotels)
18:00 onwards	Welcome Dinner at Mayor's Office

Day 2 – 24 November 2026

08:30–09:00	Morning Registration & Morning Coffee
09:00–09:50	Plenary Session 5 **- Mod: Helen C. D. Tuhumury** Sustaining Small Island Aquaculture: Annual Catch Patterns and Seedstock Dynamics of Juvenile Trevally (*Caranx* spp.) in Ambon Bay. - **J.W. Mosse & B.G. Hutubessy** Chemical Characterization and Therapeutic Potential of Essential Oils from the Moluccas Islands. - **Healthy Kainama** Geographical Barriers to Timely Stroke Care: A Case Report of Hemorrhagic Stroke Referred from Bula to Ambon, Maluku, Indonesia. - **Bertha Jean Que, et al.** Pre-Feasibility Study on The Impact Of Renewable Energy on Poverty Alleviation Among Fisher and Farmer Households in Maluku - **Wardis Girsang, et al.** Geographical Distribution of Black Flies in the Amami Islands, Japan. - **Yasushi Otsuka**
09:50–10:05	Q&A Session (Plenary 5) - Mod: Helen C. D. Tuhumury
10:05–10:25	Short Break / Refreshment
10:25–11:15	Plenary Session 6 **- Mod: Suzie Suhendy** The Image Writing and Spiritual Perception of Clams in Yuan Dynasty Literature. - **Yan, Jy-Ing** A Comparative Study of Art Island Strategies: Naoshima Art Project and Shinan County's One Island–One Museum Policy. - **Sung-Hyun Park** Closing the Regional Gap in Global Competence among University Students in an Island and Coastal Region. - **Jinhee Han** Enriching the Concept of Island Socio-Ecological System (SES) and Small Island Occupation Resilience - **Rhony E. Ririhena, et al.** A Spatio-Temporal Model of Fishing Grounds Based on Local Knowledge: A Case Study of Haruku and Sameth Villages, Indonesia. - **James Abrahamz, et al.**

11:15–11:30	Q&A Session (Plenary 6) - Mod: Suzie Suhendy
11:30–12:20	Plenary Session 7 - **Mod: Maisie T. F. Tuhumury** Educational Governance for Archipelagic Sustainability: Addressing Educational Inequality in Maluku through Secondary Data and Policy Analysis. - **Paul Arjanto** From Extractivism to Ecological Restoration: An Ecotheological Perspective on Ecological Justice in Oil Palm Plantations in Latea, Maluku, Indonesia. - **Ledy Manusama, et al.** Reconstruction of a Model for Resolving Cases of Sustainable Marine Resource Violations Based on Local Wisdom in Maluku. - **Deassy J.A. Hehanussa & Yanti A. Lewerissa** Weed Vegetation Analysis and Ecological Dominance in Immature and Mature Clove Plantations (Syzygium aromaticum L.) in Hila Village, Central Maluku. - **Vilma Tanasale, et al.** Multi-Sector Participatory Action for Revitalization of the Island Cluster Healthcare System (ICHS) in Buru Regency, Maluku, Indonesia. - **Farah Christina Noya, et al.**
12:20–12:35	Q&A Session (Plenary 7) - Mod: Maisie T. F. Tuhumury
12:35–13:35	**Lunch Break & Networking**
13:35–14:25	Plenary Session 8 **- Mod: Adelina Siregar** Physicochemical Characteristics of "Bakasang", a Traditional Fermented Fish Product from Banda Islands, Indonesia. - **Raja Bonan Dolok Sormin, et al.** Small Islands Environmental Law Education: Strategies to Rediscover the Future Value of Island Regions. - **Dyah R. A. Daties** Empowering Coastal Fishermen: A Standalone Wind-Solar Micro-Hybrid System for Renewable Cold Chains. - **Wulfilla Maxmilian Rumaherang** Insect Biodiversity in Traditional Agroforestry: Exploring the Ecological Value of Dusung for Sustainable Small-Island Landscapes in Maluku, Indonesia. - **J. A. Leatemia** Socio-Ecological Resilience, Climate Adaptation, and Sustainable Agroforestry in the Maluku Islands, Indonesia - **Evelin Parera, et al**
14:25–14:40	Q&A Session (Plenary 8) - Mod: Adelina Siregar
14:40–15:00	**Closing Session:** Summary and Conclusions - **Helen C. D. Tuhumury** Vote of Thanks from Pattimura University - **Vice Rector I of Pattimura University**

Speakers Profile



Keynote Speakers

Sun-kee HONG

Professor of Institution for Marine and Island Cultures, Mokpo National University

Prof. Sun-Kee Hong is a globally recognized environmental planner and ecologist whose scholarly work bridges ecological science, island sustainability, and cultural landscape preservation across East and Southeast Asia. Earning his Ph.D. in Environmental Planning from Hiroshima University, Japan, in 1994, Prof. Hong pioneered comparative research on the ecology of inhabited and uninhabited islands, fishing villages, and maritime urban centers in South Korea, Indonesia, and Japan. Since joining Mokpo National University in 2012 as a Professor in both the Institution for Marine and Island Cultures and the Department of Liberal Arts, he has established himself as a leading authority on biocultural landscapes and archipelagic heritage. In April 2025, he was appointed Director of the Office of International Affairs at Mokpo National University, following his tenure as Dean of the School of Global Studies in January 2024. As Chairman of the Korea Island Foundation since January 2021, Prof. Hong actively drives policy advocacy, ecotourism integration, and community resilience for archipelagic regions. His global governance roles include serving as an Executive Member of the International Geographical Union (IGU) Commission of Islands (2021–present), Director Member of the Korea Ecotourism Association (2021–present), and Director Member of the 2026 Yeosu World Island Expo Organizing Committee (Dec. 2024–present). Furthermore, he serves as Chair of the Local Organizing Committee for the 20th ISISA World Island Conference in Shinan. He was major editor of a book “Ecological Issues in a Changing World – Status, Response and Strategy (Kluwer, 2004), “Landscape Ecological Applications in Man-influenced Areas: Linking Man and Nature Systems (Springer-Dordrecht, 2007)” and “Landscape Ecology in Asian Cultures (Springer-Tokyo, 2011)” also currently serving as Editor in Chief of Journal Marine & Island Cultures. He published international books titled “Biocultural Landscapes” (Springer-Verlag, 2014). Prof. Hong's dedication to environmental policy and island research has been recognized with premier national awards, including the President Commendation (2021), the Jeollanam-do Governor's Commendation (2019), the Prime Minister's Commendation (2010), and the Minister of Environment Commendation (2002). His multifaceted achievements reflect a lifetime of connecting scientific rigor with public policy for resilient island futures.

Plenary Speakers

Sota Yamamoto



Associate Professor at the International Center for Island Studies, Kagoshima University,

He completed his higher education at Kyoto University, earning academic degrees in March 2003 and March 2005 before receiving his Doctorate in March 2008. Over the past two decades, his research has bridged ethnobotany, agricultural history, and plant domestication, exploring how human cultures interact with cultivated plants and shape biodiversity conservation across Southeast Asia, Micronesia, and the Japanese island chains. A central pillar of Dr. Yamamoto's work—spanning more than 30 field publications—focuses on the cultural adoption and botanical diversity of chili peppers (*Capsicum* spp.) across Indonesia. Through extensive fieldwork in Java, Sumatra, Sulawesi, and the Maluku archipelago (including Ambon, Karimunjawa, Tanimbar, Aru, and Buru Islands), he documented the history, taxonomy, and cultivation of *Capsicum pubescens* (Cabai Gendot), establishing its economic importance as a specialized highland cash crop. He also mapped the historical distribution of C. chinense and *C. frutescens* (Cabai Rawit) throughout Eastern Indonesia, demonstrating how maritime trade networks and island geography shaped species variation and culinary preferences. Furthermore, he pioneered findings on the antimicrobial and cultural roles of chili peppers in traditional medicines, local dusung agroforestry systems on Ambon Island, and traditional rice fermentation starters (*ragi*) used for rice wine. His key research on Indonesian ethnobotany has been published in academic venues such as Tropical Agriculture & Development, The Journal of Island Studies, South Pacific Studies, and Deepublish. In recognition of his contributions to tropical agriculture and ethnobotany, Dr. Yamamoto has been honored with the Island Study Promotion Award (2014), the Japanese Society for Tropical Agriculture (JSTA) Encouragement Award (2016), and the JSTA Paper Award (2025). Active in academic organizations including the Society for Economic Botany and the International Small Island Studies Association, he continues to advance international research collaborations—such as his long-standing partnerships with Pattimura University in Ambon—to connect traditional ecological knowledge with sustainable island futures

Plenary Speakers



Hermien L. Soselisa

Professor of Anthropology at Pattimura University

Prof. Dr. Hermien Lola Soselisa, M.A. is a Born in Ambon, she built her scholarly foundation at Universitas Gadjah Mada (UGM), graduating with a degree in Cultural Anthropology in 1987 with a study on Javanese ritual balance. She subsequently earned her Master of Arts from Northern Territory University in 1996, researching island subsistence, markets, and Garogos Island production, before completing her Ph.D. at Charles Darwin University in 2003 on customary resource management in Central Maluku. Specializing in maritime anthropology and island resilience, Prof. Soselisa's research from 2021 to 2025 centers on three interconnected themes. In maritime anthropology and indigenous tenure, she examines customary marine governance, traditional *sasi* institutions, and maritime tenure across Seram, Ambon, and the Lease Islands. Her work on small-island socio-ecological resilience explores adaptive strategies in coastal fisheries, including mud crab fisheries in Kei Kecil and flying fish egg exploitation, while her biocultural heritage and food security research documents ancient rock art motifs in Southwestern Maluku textiles, customary pottery traditions in Ouw, and traditional crops such as canarium fruit and breadfruit. Between 2021 and 2025, she published more than 17 global papers and three major authored books: *Merampas Laut Merampas Hidup Nelayan: Coastal & Marine Grabbing in Indonesia & Philippines* (2025), and *Suara Leluhur dari Pulau-Pulau* (2025). Her peer-reviewed articles published in outlets such as the *Singapore Journal of Tropical Geography*, *IOP Earth & Environmental Science*, and *Food Research* address biocultural conservation in Maluku, traditional fishery regulations in Kei Kecil, coastal seafood consumption on Ambon Island, women and boat rock art along Southeast Maluku maritime routes, and small-island agro-ecological systems. She has shared these findings at international forums including the Anthropology & Conservation conference in London (2021), the Indo-Pacific Prehistory Congress in Thailand (2022), the Taiwan–Southeast Asia Workshop in the Philippines (2022), and the Leiden Expedition Workshop (2024), while also collaborating with WWF-Indonesia, BPK Maluku, and provincial agencies to advance community-based marine conservation, cultural heritage preservation, and sustainable small-island tourism.

Keynote Address

Sustaining Islandness through Resilience: Eco-Cultural Diversity and Socio-Ecological Transition in Island Communities

Sun-Kee HONG
Institution for Marine and Island Cultures, Mokpo National University

Abstract

This presentation examines the sustainability of islandness through the lens of eco-cultural diversity, socio-ecological transition, and resilience in the era of climate crisis. By comparing islands in the Korean Peninsula, Japan, and Indonesia, it explores how island livelihoods, traditional ecological knowledge, community practices, and cultural landscapes are shaped by changing environments, population decline, tourism pressure, and livelihood transformation. The study argues that islandness is not a product of isolation, but an accumulation of relationships among nature, culture, knowledge, and community. It also emphasizes collaborative governance among local communities, universities, researchers, and policy institutions for sustainable island futures.

Keywords: Islandness; Eco-cultural diversity; Biocultural diversity; Socio-ecological resilience; Climate crisis; Collaborative governance

This presentation aims to reinterpret the identity and ways of life of islands in the era of climate crisis by comparing islands in the Korean Peninsula, Japan, and Indonesia. It also seeks to examine, from humanities and socio-ecological perspectives, the meaning and value of the distinctive eco-cultural diversity of islands. Today, islands are situated at the frontline of complex transitions, including climate change, changes in the marine environment, population decline, tourism pressure, shifts in livelihood structures, and land-use change (Ariando and Arunotai, 2022). These changes are not limited to the natural environment; they also deeply affect the everyday lives and livelihoods of island residents, community relations, traditional knowledge, cultural landscapes, and local identity. Therefore, it is not sufficient to understand islands merely as physical spaces or as administrative and economic units. Islands should be understood as socio-ecological living spaces formed through long-term interactions among humans and nature, livelihoods and culture, knowledge and community (Pathirana, 2025). Island residents have lived by reading the changes of the sea and tidal flats, forests and villages, fishing grounds and coasts, seasons and tides. In this process, they have accumulated livelihood practices, community norms, rituals and beliefs, everyday culture, and traditional ecological knowledge. These accumulated relationships constitute the identity of islands and form the core of what this presentation refers to as “islandness.” Islandness cannot be explained only by geographical conditions or isolation surrounded by the sea (Campbell, 2009; Hong, 2023). Rather, it is the outcome of relationships formed as island residents have understood their natural environment, used resources, responded to risks, and sustained livelihoods and communities. In other words, islandness is not the result of isolation but the accumulation of relationships (Hong, 2023). It can be understood as a form in which biological diversity, cultural diversity, local knowledge, and ways of life are condensed within island spaces (Berkes et al., 2000). From this perspective, island eco-cultural diversity becomes a key concept for understanding the sustainability and resilience of islands.

This presentation takes the concepts of eco-cultural diversity, biocultural diversity, islandness, and socio-ecological resilience as its theoretical foundation. Eco-cultural diversity refers to the perspective that natural environments and cultural practices do not exist separately, but are formed and transformed together through interaction. Biocultural diversity emphasizes that biological diversity, cultural diversity, and the diversity of language and knowledge are interconnected. From this perspective, tidal flats, salt fields, fishing grounds, village forests, coastal landscapes, aquaculture

grounds, livelihood activities, rituals, and traditional ecological knowledge should not be seen as separate elements, but as an integrated system that constitutes island life.

The islands of the Korean Peninsula feature eco-cultural landscapes where livelihoods and ecological environments are closely intertwined, including tidal flats, salt fields, communal fishing grounds, *haenyeo* culture, fishing village cooperatives, village forests, and aquaculture (Samantha and Hong, 2019). In particular, the islands in the southwestern sea region have developed a distinctive island culture through the interplay of tidal ranges, tidal-flat ecosystems, marine biological resources, and community-based autonomous management practices. In this region, the sea is not simply a production space, but a living world in which residents' lives, memories, labor, and community norms have accumulated. However, recent climate change, aging, population decline, and structural changes in fisheries and aquaculture are shaking this eco-cultural foundation and raising new questions about island sustainability.

The islands of Japan clearly reveal issues related to traditional ecological knowledge, rituals, community autonomy, and the continuity and decline of local culture. In many Japanese island regions, fisheries, seaweed use, forest and coastal management, village festivals, and local beliefs have been closely connected with the ecological environment. However, aging, out-migration, weakening local economies, and tourism-centered restructuring have made the sustainability of island communities increasingly difficult. At the same time, some islands are seeking new possibilities for transition through ecotourism, cultural heritage conservation, and resident-led regional revitalization based on traditional culture and local resources. The experiences of Japanese islands show how tradition and modernity, conservation and utilization, local identity and the tourism economy are placed in tension and negotiated. The islands of Indonesia provide important cases for examining maritime mobility, fishing knowledge, coral reef and mangrove ecosystems, multiethnic and multicultural communities, and the tensions between tourism development and environmental change. Indonesia is an archipelagic state composed of numerous islands, and many island residents have understood the sea not as a boundary, but as a space of movement and exchange. Fishing activities, marine resource use, navigational knowledge, local beliefs, and rituals are closely connected with island residents' lives. However, climate change, sea-level rise, coral reef degradation, tourism development, and the inflow of external capital have brought significant changes to island ecosystems and community cultures. In particular, on tourist islands, the commodification of local culture, changes in everyday life, and conflicts between residents and outside visitors have emerged as important issues. Although the islands of the Korean Peninsula, Japan, and Indonesia have different histories, cultures, and ecological environments, they share several important issues. First, island livelihoods are not simply economic activities, but eco-cultural practices that combine the natural environment and community culture. Second, the traditional ecological knowledge of island residents is an important asset for responding to the climate crisis and environmental change. Third, climate change, population decline, and tourism pressure simultaneously affect both biological diversity and cultural diversity on islands. Fourth, island sustainability cannot be achieved through nature conservation alone. It becomes possible only when the continuity of livelihoods, community participation, the transmission of local culture, scientific and technological responses, and policy support work together.

In this sense, the climate crisis should be understood not merely as an environmental issue, but as a humanities and socio-ecological challenge that demands a transition in island residents' ways of life, culture, livelihoods, and communities. Climate vulnerability assessments and studies of residents' perceptions can serve as important methods for understanding this transition. Examining how island residents and stakeholders experience and interpret environmental change, and what kinds of adaptation strategies they create at the community level, is essential for understanding the eco-cultural resilience of islands. Island resilience does not simply mean the ability to withstand external shocks and

return to a previous state. Rather, it refers to the capacity to create new sustainable ways of life by connecting nature and culture, livelihoods and communities, traditional knowledge and science and technology, conservation and regional development. The tidal flats and communal fishing grounds of Korean islands, the rituals and regional revitalization efforts of Japanese islands, and the maritime mobility and traditional fishing knowledge of Indonesian islands are all expressions of the diverse ways in which island communities have responded to change.

However, such resilience cannot be secured through the efforts of local communities alone (Berkes and Folke, 1998). Since the climate crisis, population decline, industrial restructuring, and tourism development pressure are complex issues, collaborative governance involving local communities, universities, researchers, administrative bodies, and policy institutions is necessary. Local communities provide the lived realities and experiential knowledge of island life; universities and researchers systematically analyze and theorize them; and administrative and policy institutions must establish practical systems of support and implementation. In island studies, participatory research that respects residents' voices and local knowledge, field-based education, and problem-solving collaborative research are especially important.

Universities can play a crucial mediating role within this cooperative structure. A university can serve as a research institution that investigates and records the eco-cultural resources of island regions, an educational institution that nurtures future generations, and a public platform that connects local communities with administrative systems. Researchers should not merely observe islands from the outside. Rather, they should work with residents to define problems, interpret the meaning of change, and jointly develop strategies for sustainable transition. Governance, likewise, should not be limited to administrative management; it should be a collaborative decision-making process that considers island residents' lives and cultures, ecological environments, and the rights of future generations. Ultimately, this presentation seeks to redefine islands as spaces of eco-cultural transition. Islands are vulnerable spaces in the face of climate crisis and population decline, but they are also important sites where we can learn how humans and nature may rebuild their relationships. Islands hold accumulated knowledge for reading nature, techniques for sustaining livelihoods, norms for maintaining communities, and practices for adapting to change. Reinterpreting these assets and connecting them to policy is an important task for island studies in this age of transition.

In conclusion, the future value of islands begins with integrated thinking that does not separate nature from culture. Protecting the eco-cultural diversity of islands means protecting the lives and knowledge of island residents, their livelihoods and communities, and the sustainability of future generations. To realize this goal, an open knowledge community is needed, one in which local communities, universities, researchers, administrative bodies, and policy governance work together. This is the new meaning of islandness in the era of climate crisis, and it is the direction in which sustainable island humanities and socio-ecological transition studies should move.

Acknowledgements

This research was supported by the Humanities Korea Plus (HK+) Project of the National Research Foundation of Korea (Grant No. 2020S1A6A3A01109908).

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Plenary Speakers

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EAIOF 2026 - Full-text Abstracts

Agroforestry (*dusung*) in Ambon Island, Indonesia: Relationship between slope gradient and tree species within four plots

Sota Yamamoto[1], Rico Hachisuka[2], Nobuhiko Komaki[3], Tomohiro Kondo[4], Daisuke Uyeno[5], Jeter D. Siwalette[6], and Wardis Girsang[6]

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Abstract:

Agroforestry systems called *dusung* has been practiced for a long time in Maluku Province, Indonesia. In the *dusung*, spice, fruit, palm, and crops are cultivated. Even though the *dusung* is socio-economically very important, detailed agricultural practices have not been well studied. Therefore, we selected one household possessing four plots of the *dusung* in Allang Village of Ambon Island, where the capital of Maluku Province is located, and explored species composition patterns. In this study, we would like to focus on 1) species composition and characteristics and 2) conscious/unconscious cultivation management.

Keywords: clove, conscious/unconscious cultivation management, nutmeg, species composition and characteristics, sugar palm (*Arenga pinnata*)

Indigenous agroforestry systems called *dusung* has been practiced for a long time in Maluku Province, Indonesia. In the *dusung*, spice (clove and nutmeg), fruit (durian, mangosteen, langsat, breadfruit, jackfruit, etc.), palm (coconut, sago palm, and sugar palm), and crops (cassava, sweet potato, taro, cocoyam, banana, maize, various vegetables, etc.) are cultivated. Local people recognize the *dusung* as one ecosystem from forest to sea, such as forest (*ewang*), multiple tree crops (*dusung* in the narrow sense), fallow land (*a'ong*), house yard, homegarden, and horticultural land (*kintal* and *kabong*), and coastal area (*mange-mange*, *pesisir*, and *laut*; Fig. 1). Even though the *dusung* is socio-economically very important, detailed agricultural practices, including crop selection, planting, and management, especially on multiple tree crops have not been well studied.

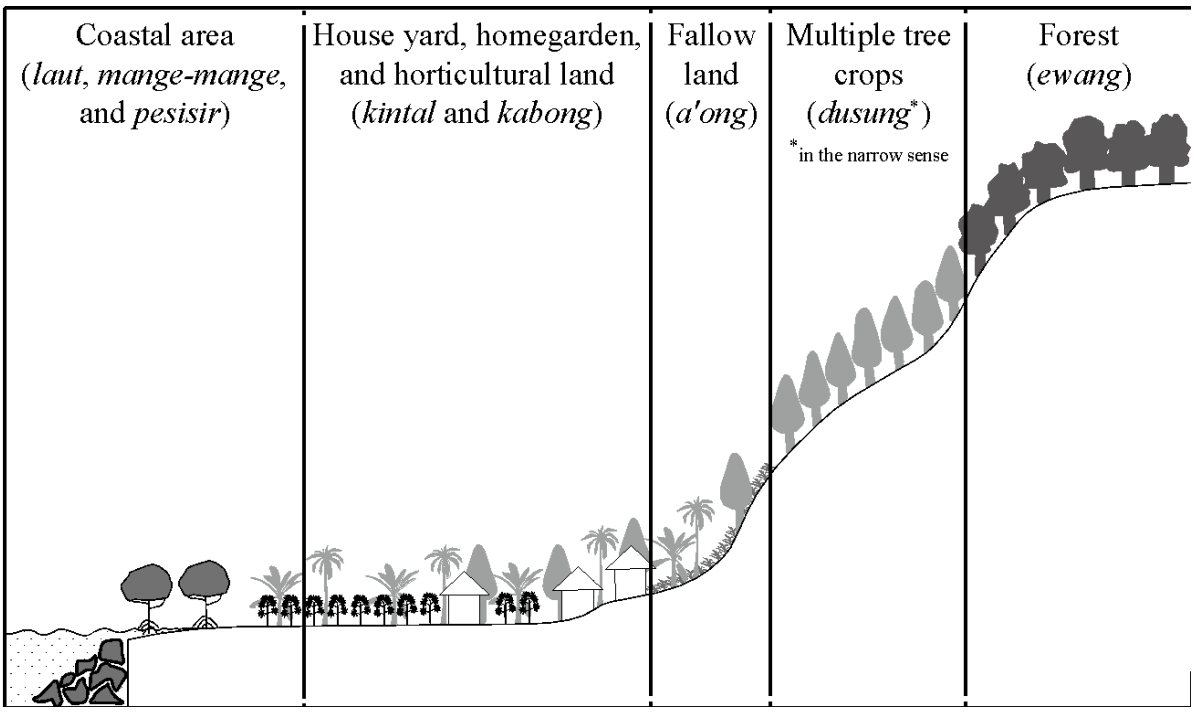


Fig. 1. Schematic diagram of agroforestry systems (*dusung*) in Maluku Province, Indonesia.

Therefore, we selected one household possessing four plots (Hutil, Wetita, Hatunang, and Wailulung) of the *dusung* (in the narrow sense) in Allang Village, West Leihitu District, Central Maluku Regency, measured them with level survey, and explored species composition patterns there in January and October, 2024 and March, 2025 (Fig. 2). Within the plots, we conducted a census of all living useful trees > 1.3 m tall; we identified useful tree species and recorded diameter at breast height (1.3m), tree height, tree age, and the position of each individual.

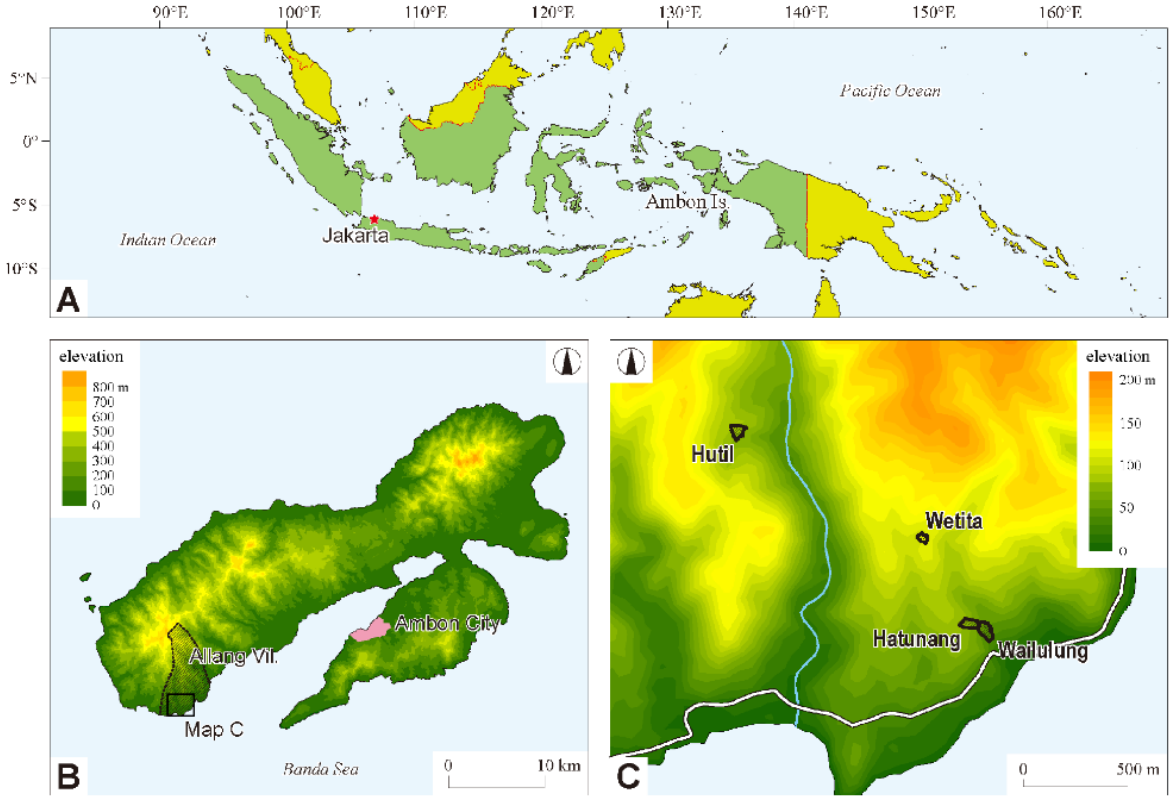


Fig. 2. Study site.

1,079 trees (40 species in 22 families) were recorded in the four plots. *Mayang* (sugar palm; *Arenga pinnata*), *gayang* (*Inocarpus fagifer*), *duku* (*Lansium domesticum*), and *langsa* (*L. domesticum*) were found in all plots, indicating that they are likely to distribute widely in this area (Table 1). All the individuals of *mayang* (267) and *gayang* (28) were spontaneous (wild; the household did not plant them). On the other hand, focusing on *duku* (planted 64/spontaneous 92) and *langsa* (10/317), it is clear that the number of planted *duku* trees was significantly higher than *langsa*. The unit price of *duku* fruit is approximately twice that of *langsa*, revealing that *langsa* cultivation is managed considerably more extensively than *duku*.

Table 2. Tree species found in more than two plots of the *dusung* owned by the surveyed household in Allang Village, Ambon Island, Maluku Province, Indonesia.

Sicentific name	Local name	Plot name			
		Hutil	Wetita	Hatunang	Wailulung
Arenga pinnata	*mayang*	+	+	+	+
Inocarpus fagifer	*gayang*	+	+	+	+
Lansium domesticum	*duku*	+	+	+	+
Lansium domesticum	*langsa*	+	+	+	+
Myristica fragrans	*pala*	+	+	+	-
Syzygium aromaticum	*cengkeh*	+	+	+	-
Alstonia scholaris	*pule*	+	-	+	+
Canarium ovatum	*kanari*	+	-	+	+
Cocos nucifera	*klapa*	+	-	+	+
Durio zibethinus	*duriang*	+	-	+	+
Gnetum gnemon	*ganemu*	+	-	+	+
Pterocarpus indicus	*lenggua*	+	-	+	+
Bouea macrophylla	*gandaria*	+	-	-	+
Clerodendrum minahassae	*mate*	+	-	-	+
Parkia speciosa	*pate*	+	-	-	+
Annona muricata	*nangka blanda*	-	+	-	+
Mangifera indica	*mangga*	-	+	-	+
Vitex cofassus	*gupasa*	-	-	+	+

Table 2. Tree species found in more than two plots of the *dusung* owned by the surveyed household in Allang Village, Ambon Island, Maluku Province, Indonesia.

Sicentific name	Local name	Plot name			
		Hutil	Wetita	Hatunang	Wailulung
Arenga pinnata	*mayang*	+	+	+	+
Inocarpus fagifer	*gayang*	+	+	+	+
Lansium domesticum	*duku*	+	+	+	+
Lansium domesticum	*langsa*	+	+	+	+
Myristica fragrans	*pala*	+	+	+	-
Syzygium aromaticum	*cengkeh*	+	+	+	-
Alstonia scholaris	*pule*	+	-	+	+
Canarium ovatum	*kanari*	+	-	+	+
Cocos nucifera	*klapa*	+	-	+	+
Durio zibethinus	*duriang*	+	-	+	+
Gnetum gnemon	*ganemu*	+	-	+	+
Pterocarpus indicus	*lenggua*	+	-	+	+
Bouea macrophylla	*gandaria*	+	-	-	+
Clerodendrum minahassae	*mate*	+	-	-	+
Parkia speciosa	*pate*	+	-	-	+
Annona muricata	*nangka blanda*	-	+	-	+
Mangifera indica	*mangga*	-	+	-	+
Vitex cofassus	*gupasa*	-	-	+	+

Pala (nutmeg; *Myristica fragrans*) (planted 61/spontaneous 3) and *cengkeh* (clove; *Syzygium aromaticum*) (48/1) distributed in all four plots except the Wailulung plot. Nearly all the individuals of the high-value spice plants *pala* and *cengkeh* are cultivated, indicating they are intensively managed for cultivation. The surveyed households mentioned that "the nutmeg trees were once found in Wailulung but died off about 30 years ago," "we haven't planted clove trees in Wailulung because the soil isn't suitable," and "areas littered with rocks and stones are not suitable for nutmeg and clove trees." Based on these comments, natural environmental factors were considered one of the reasons why nutmeg and clove trees were not found in Wailulung.

Pule (*Alstonia scholaris*) (planted 0/spontaneous 5), *kanari* (*Canarium ovatum*) (0/24, 1 unknown), *klapa* (coconut; *Cocos nucifera*) (13/3), *duriang* (durian; *Durio zibethinus*) (2/9, 1 unknown), *ganemu* (*Gnetum gnemon*) (0/23), and *lenggua* (*Pterocarpus indicus*) (2/29) distributed in all plots except the Wetita plot.

Pala, *cengkeh*, coconut, and various vegetable tress used daily are intentionally (consciously) planted. However, does not the household take care about other tree species? It seems that people have skillfully selected trees that "grow on their own" in the Ambon Island's natural environment.

Factors contributing to the sustainable use of the *dusung* despite impacts from changes in natural and social environments are 1) intentional cultivation management adapted to changing natural and social environments and 2) the "conscious" and/or "unconscious" utilization of tree species suited to the natural environment of Ambon Island.

Navigating Sustainability: Island Cultures and Multivocal Conservation in Maluku

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Abstract

Island communities face disproportionate vulnerabilities to climate change and biodiversity loss, yet top-down conservation frameworks frequently marginalize their cultural heritage and indigenous ecological knowledge. Focusing on the Maluku archipelago of Eastern Indonesia—a vital part of the Wallacea biogeographical transition zone—this presentation explores the intersection of island culture and contemporary environmental governance. It highlights a critical tension: while state hegemony and market commodification often sideline local customary frameworks, they are simultaneously co-opted to serve global conservation agendas and market interests.

Drawing on qualitative field research and narrative analysis, this study examines how island identity shapes ecological resilience and how traditional resource management practices, by focusing on the *sasi* system, can inform modern conservation models. While *sasi* has become an icon of community-based conservation, portraying it as an "indigenous" or "resource management" system often serves political and economic ends that extend beyond ecological stewardship. Analyzing the discourse on *sasi* reveals a multivocal landscape of different aspects of the conservation-development conjuncture.

Present biocultural diversity in the Wallacea-Maluku region is the result of patterns of human-resource interaction at different periods in the past. Consequently, research, conservation interventions, and effective ecosystem practices require greater attention to historical ecology and socio-culture, local knowledge systems and diverse, locally specific forms of conservation.

Keywords: *Sasi, Maluku, Biocultural Diversity, Multivocal Conservation, Historical Ecology.*

Maritime Archaeology and the Archipelagic Character of the Ryukyus: A Historiography

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Abstract:

This paper argues that the archipelagic character of the Ryukyus consists precisely in its plurality, traced here through three postwar episodes concerning Miyako and Yaeyama. The first is the dispute between the Yaeyama-born linguist Miyara Tōsō, who classified Yaeyaman within the Japanese dialect continuum, and the archaeologists Kanaseki Takeo and Kokubu Naoichi, postwar repatriates from colonial Taiwan, whose stone-adze evidence pointed toward the islands' independent southern connections. The second is George H. Kerr's Ryukyu-centered general history, commissioned by the U.S. Civil Administration of the Ryukyu Islands, which nonetheless remained anchored to the Shuri literati tradition and so continued to marginalize these islands. The third is the archaeological field survey Kerr organized in the early 1960s in response to Kanaseki's and Kokubu's findings, recovering Chinese ceramics that evidence independent maritime trade networks predating Shuri domination.

Keywords: Ryukyuan history, archipelagic plurality, Miyako and Yaeyama, Chinese export ceramics, maritime archaeology

Introduction

This paper argues that archipelagic character consists precisely in its plurality: an archipelago is not a single cultural or political body extended over scattered islands, but a field of multiple, only partially overlapping histories, each anchored in a different island or island group. Postwar Ryukyuan historiography has nonetheless tended to describe the Ryukyus as a single sphere organized around the Ryukyu Kingdom and its capital at Shuri — a singularity achieved only at the expense of that plural character. Miyako and Yaeyama, some 300 and 400 kilometers respectively southwest of Okinawa Island, entered that sphere late and by force left behind almost no written record of their own history. Because the surviving textual sources were produced by the Shuri-Naha elite, text-based historiography has reproduced that elite's own indifference toward these outlying islands. This paper traces three postwar episodes in which that indifference was contested or reproduced: the dispute between the linguist Miyara Tōsō and the archaeologists Kanaseki Takeo and Kokubu Naoichi over Yaeyaman affiliation; the construction of George H. Kerr's Ryukyu-centered general history; and the archaeological field surveys Kerr organized in the early 1960s in response to Kanaseki's and Kokubu's findings.

1. The Postwar Dispute over Yaeyaman Affiliation

In the years immediately following the Second World War, the question of whether the Ryukyu Islands formed a single cultural unit was not merely academic; it bore on the islands' political status under American administration. The linguist Miyara Tōsō [宮良当壮], himself a native of Yaeyama, classified Yaeyaman speech as a dialect within the Japanese language — a position consistent with the broader claim that the Ryukyus belonged within the Japanese linguistic and cultural sphere. The archaeologists Kanaseki Takeo [金関丈夫] and Kokubu Naoichi [国分直一], both of whom had built their careers in colonial Taiwan and returned to Japan with the postwar repatriation, drew attention to material culture that complicated this picture: stone adzes recovered from Yaeyama sites showed typological affinities with the Philippines, suggesting prehistoric contact across the sea to the south rather than contact with the Ryukyu core to the north. This early disagreement established a pattern: documentary and linguistic evidence tended to fold Miyako and Yaeyama into a unified Ryukyuan or Japanese cultural sphere, while archaeological evidence pointed toward independent connections centered on the southern islands themselves.

2. A Ryukyu-Centered History

During the period of American administration, an American historian, George H. Kerr, undertook, on commission from the U.S. Civil Administration of the Ryukyu Islands, the compilation of a general history of the Ryukyus, submitted in mimeograph in 1953 and commercially published later as *Okinawa: The History of an Island People* (1958). His project was explicitly conceived as a corrective to existing Japan-centered historiography, establishing the Ryukyu Kingdom as an independent actor in the international relations and thereby strengthening Okinawan self-representation vis-à-vis mainland Japan.

Yet the sources on which Kerr relied, supplemented by discussion with Okinawan collaborators such as Higa Shuncho [比嘉春潮] and Nakahara Zenchu [仲原善忠] — were themselves products of the Shuri-Naha literati tradition. Miyako and Yaeyama accordingly remained peripheral within Kerr's narrative, treated as dependencies of Shuri rather than as historical subjects. According to A. P. Jenkins, Kerr had come to recognize this imbalance and hoped to revise his history to give Miyako and Yaeyama a more properly grounded place. Jenkins characterizes this as an ironic complication: Kerr's history had been criticized for encouraging Okinawan localism against Japan, yet correcting its internal Shuri-centrism would have required Kerr to deepen the very tendency for which the work had already been attacked.

3. From Cultural Survey to Archaeological Field Survey

The occasion for this reconsideration was a pair of large-scale field projects Kerr organized in the early 1960s with support from the Rockefeller Foundation and the Honolulu Academy of Arts. The first, conducted in 1960 as the Ryukyu Cultural Survey, was framed explicitly as salvage research: rapid postwar land development was destroying an island heritage already neglected under prewar Japanese rule. Waseda University archaeologists Takiguchi Hiroshi [滝口宏] and Nishimura Masae [西村正衛] joined the project, conducting fieldwork in Yaeyama between August and September 1960 and building on their own 1959 survey there. The wider team, which included the Academy's photographer Raymond Satow, ultimately visited thirty-nine islands and recorded 114 historic sites and 184 prehistoric remains.

Kerr conceived that second project, the Ryukyu Archaeological Field Survey, a systematic archaeological survey of the outlying islands, in response to the earlier findings of Kanaseki and Kokubu. The project began with preparatory research in the spring of 1962 by Erika Kaneko [金子エリカ] (Tokyo Metropolitan University) and Kim Won-yong [金元龍] (Seoul National University), followed by a full field season from October 1962 to early 1963 led by Kerr together with the then young archaeologist Richard J. Pearson, in cooperation with the Government of the Ryukyu Islands Museum and the Ryukyu Cultural Property Protection Commission. Kaneko combined careful attention to megalithic tombs with a critique of what she called Okinawans' own "cultural suicide" — a tendency to devalue local heritage in favor of an aspirational Japanese identity, hastening the loss of the very heritage the survey had been organized to record.

4. Miyako and Yaeyama as Historical Subjects

The Pearson–Kerr survey of the outlying islands produced results bearing directly on the question of Ryukyuan plurality. On Kuroshima, the team recorded nineteen sites, ten of them *gusuku* (a hilltop fortification); on the smaller Taketomi, twenty-six sites, six of them *gusuku*. On Hateruma, thirty-four sites were recorded, eleven of them *gusuku*, together with the remains of numerous abandoned settlements — evidence of a considerably larger premodern population. More striking still was the ceramic evidence: Hateruma sites yielded quantities of honey-brown glazed sherds consistent with Annamese or south Chinese manufacture, while around the harbor at Kumi on Iriomote, surface collection recovered large numbers of celadon and other ceramic fragments at sites classified as shell

middens. On Ishigaki, thirty minutes of surface collection at a single beach — the Shitadaru shore on Nagura Bay, first shown to Kerr in 1961 by a local schoolboy, Ohama Eino, and revisited with Pearson the following year — yielded ninety-three celadon sherds; the site eventually produced 659 fragments in total, which Pearson interpreted as possible evidence of a wrecked trading vessel in the bay.

Across the full 1962–63 survey, the team collected 1,153 celadon sherds, 162 white-bodied ware fragments, 73 blue-and-white porcelain fragments, 1,527 pieces of southern (Annamese-type) stoneware, 6,260 pieces of Panari ware (unglazed, hand-built pottery produced until the 19th century), and 60 pieces of locally made Yaeyama utility ware datable to after 1635. At Kerr's request, the ceramic specialist Koyama Fujio examined the collection and identified a substantial component as Longquan celadon of the Yuan through early Ming period, produced in Zhejiang. This finding established that Yaeyama had been actively integrated into the circulation networks of Chinese export ceramics.

5. Ceramics against the Shuri Narrative

The interpretive weight of this material evidence lies in what it implies about the political economy of the southern islands before their incorporation into the Ryukyu Kingdom's administrative structure. The quality and volume of the recovered ceramics indicate a population large and prosperous enough to sustain maritime trade with China independent of Shuri intermediation — a history nowhere recorded in the official chronicles of the Ryukyu Kingdom. The ceramic record also registers subsequent decline: on islands such as Hatoma, left uninhabited for a period and later resettled after the Satsuma invasion of 1609, the later occupation layers show markedly inferior wares, suggesting that incorporation into the Satsuma-Ryukyu tribute system corresponded with a loss of the islands' earlier independent prosperity.

In this sense the Ryukyu Archaeological Field Survey did more than recover artifacts: it offered a method for writing Miyako and Yaeyama into history as subjects rather than as peripheral objects of Shuri administration. Whereas the textual record, produced by and for a Shuri-centered elite, structurally marginalizes the outlying islands, archaeological evidence has been well positioned to recover their independent historical agency.

Conclusion

The postwar historiography of Miyako and Yaeyama is best understood as a series of discourses in which successive research projects reopened the question of Ryukyuan plurality. The episodes discussed complicates any narrative that subsumes these outlying islands within a single Ryukyuan framework: the early postwar dispute between Miyara and the Taiwan-trained archaeologists; the construction, under American administration, of a Ryukyu-centered history that inherited the Shuri literati tradition's own marginalization of the outlying islands; and the 1960s archaeological surveys that recovered independent maritime trade networks predating and exceeding Shuri's reach. The archipelagic character of the Ryukyus consists not in geography but in this plurality itself.

Notes

1. On Miyara-Kanaseki debate and related discussions, see, Ken'ichi Tanigawa, ed., *Kigen Ronsō [The Origins Debate], Sōsho Waga Okinawa [Series: Our Okinawa]*, vol. 3 (Tokyo: Mokujisha, 1971).
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3. A. P. Jenkins, "G. H. Kerr's Okinawa: The History of an Island People and Beyond," *The Ryukyuanist*, no. 52 (2001): 3–8.
4. George H. Kerr, "The Ceramics Story in the Ryukyus: Rare Products and Precious Treasures," in *Chinese Ceramics Excavated in Okinawa*, Vol. 1: Yaeyama, ed. Okinawa Prefectural Museum (Naha: Okinawa Prefectural Museum, 1982), pp. 115–120, and George H. Kerr, "The Ryukyu Cultural Assets Survey Project, 1961–1964," in *Chinese Ceramics Excavated in Okinawa*, Vol. 2: Okinawa Main Island, ed. Okinawa Prefectural Museum (Naha: Okinawa Prefectural Museum, 1983), pp. 89–96.

Nature-based Solutions for Land Use and Climate Change in Islands and Coastal Areas: A Case Study of Shinan and Muan

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Abstract

This study examines the relationships between land use, climate, and nature-based adaptation in Muan and Shinan, South Korea. Using 2014 land-cover and 2001–2010 meteorological data, Pearson's correlation analysis assessed associations between six land-use categories and eight climatic indicators. Results show that built-up and agricultural areas correlate with higher maximum temperatures and increased thermal vulnerability. Conversely, forests and grasslands provide significant cooling effects, acting as natural buffers. Wetlands and water bodies regulate hydrology while potentially retaining nocturnal heat. These findings highlight the importance of nature-based land management, such as forest expansion and wetland conservation, for mitigating heat stress. Furthermore, the study emphasizes extending national climate adaptation policies beyond urban areas to protect vulnerable, aging coastal and island populations facing intensifying climate change.

Keywords: coastal and island regions, climate change, tropical night, Republic of Korea

1. Introduction

South Korea is a peninsula surrounded by the sea on three sides, with approximately 3,300 islands and an extensive coastline. Traditionally, these regions exhibit a maritime climate with warmer winters and cooler summers, providing a milder annual temperature range that directly influences local ecosystems and industries like fishing and tourism (Griggs & Reguero, 2021). However, islands and coastal areas are increasingly vulnerable to climate change. Sea-level rise causes coastal erosion, and while longer summers have expanded the tourism season, they have also degraded the quality of the environment (Rawat et al. 2016). Furthermore, longer summers driven by climate change are expanding heatwaves and tropical nights across broader areas.

While urban tropical nights typically see temperatures drop by dawn, island and coastal tropical nights are characterized by persistently high temperatures even at dawn (Pielke et al. 2019). In South Korea, excluding coastal cities like Busan, these regions are predominantly populated by the elderly. Due to low populations and the lingering notion that these areas are naturally cooler, efficient policies to mitigate tropical nights are lacking, leaving residents to suffer significantly. Although land use plays a crucial role in accelerating or mitigating such phenomena, few studies have examined the relationship between land use and climate in South Korean island and coastal regions (Barati et al. 2019).

Therefore, this paper aims to examine the relationship between current meteorological conditions and land use in these regions, providing foundational data to support vulnerable elderly residents.

2. Materials and Methods

2.1 Study areas

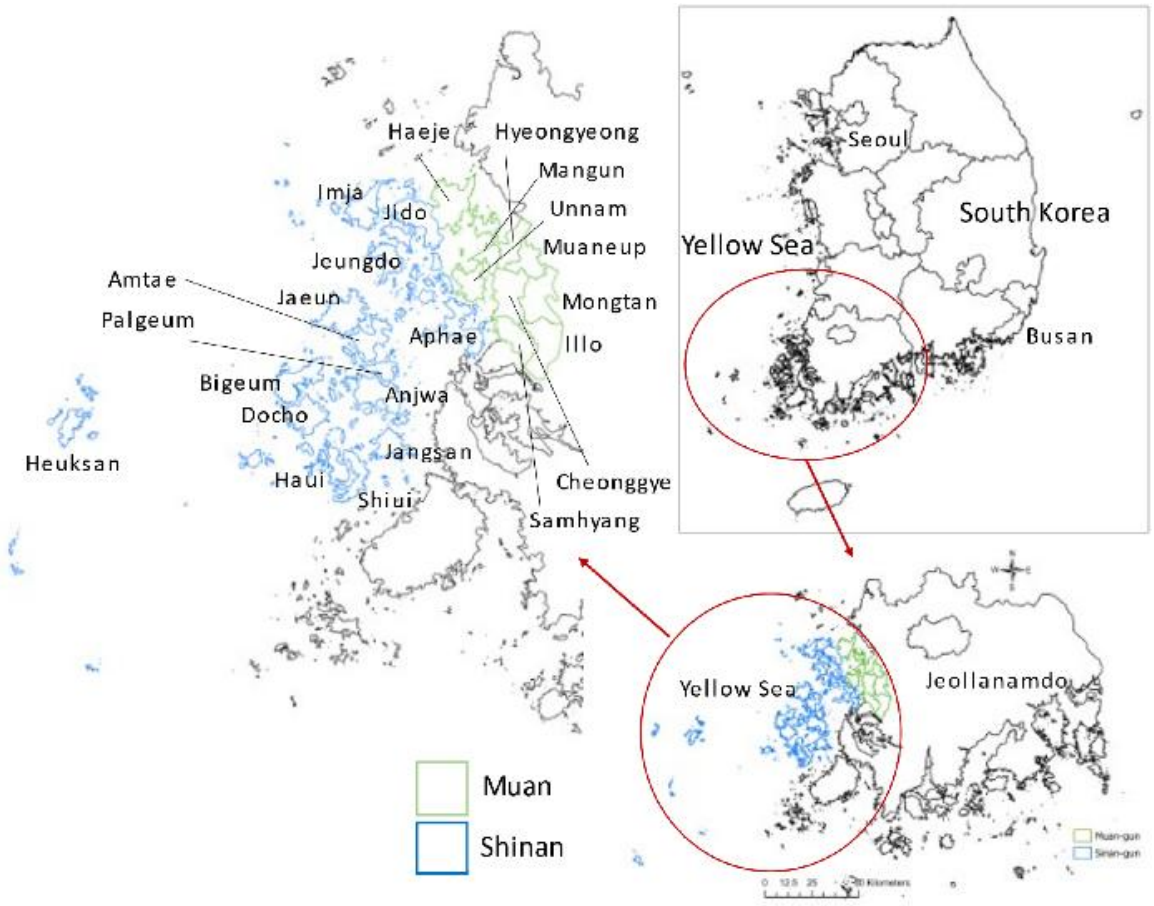


Figure 1. Location of Study areas

Table 1. Profile of the study areas (Muan and Shinan)

Item	Muan	Shinan
Area	436.40 km^2	655.68 km^2
Human population (2020)	86,132	38,938
Population density	197.37 persons km^2	59.38 persons km^2
Economy	Mainly agriculture; limited aquaculture	Mixed farming, fishing, and aquaculture
Administrative units	3 eups and 6 myeons (9 local offices)	2 eups and 12 myeons (14 local offices)
Natural environments	Muan Tidal Flat Wetland Protected Area	UNESCO World Heritage (Getbol), UNESCO Shinan-Dadohae Biosphere Reserve, Dadohaehaesang National Park
Geographical features	North–south elongated terrain; most hills 200–300 m above sea level; extensive reclaimed tidal flats converted to cropland since the 1960s	2 eups and 12 myeons (14 local offices) Composed of ~890 islands; mostly rolling hills 200–300 m above sea level; broad tidal flats

2.2 Methods

2.2.1 Land use and Climate data

Land use reflects regional socio-economic traits and cultural perspectives on human interaction with nature [Reference]. The land use maps for the two regions were reprocessed into six major categories using the Ministry of Environment's 2014 land cover maps to calculate areas and metrics.

While South Korea monitors weather nationwide, measurements are rarely conducted down to the small township (myeon) level, making localized comparisons difficult. Sinan-gun has one ASOS and 11 AWS stations, while Muan-gun has four AWS stations and no ASOS, posing challenges for high-resolution local weather tracking.

The meteorological data used in this study—spanning 2001 to 2010—were provided by the Korea Meteorological Administration to support regional climate change adaptation using high-resolution satellite data and observation equipment.

2.2.2 Correlation analysis

Land uses representing habitats are generally known to be positively, negatively, or independently correlated with each other (Kim, 2016. Correlation analysis is commonly used to examine the relationship between land use and other factors. Correlation analysis has been used to examine the relationship between land use and climate change, which di-rectly affects ecosystem services. Spearman correlation analysis assesses the strength and direction of monotonicity between two variables. Spearman analysis was performed because Spearman correlation coefficient is less sensitive to outliers than Pearson correla-tion analysis and does not require distributional assumptions, making it suitable for nonparametric data (Marando et al. 2022).

To examine land–climate interactions, we calculated Spearman correlation coeffi-cients (r) between the proportional area of each land-use category (by eup/myeon, admin-istrative unit) and the 10-year mean meteorological variables using IBM SPSS Statistics 26. Significance thresholds were set at $p < 0.05$ and $p < 0.01$.

3. Results and Discussions

The analysis identified significant relationships between land-use patterns and climatic variables in the coastal and island regions of Muan and Shinan. Muan was characterized by extensive agricultural land and forests, whereas Shinan showed a mixed landscape consisting of forests, tidal wetlands, and agricultural land shaped by historical land reclamation. These contrasting land-use characteristics reflect differences in their economic structures and provide an important basis for understanding regional climate responses.

Spearman correlation analysis showed that both built-up and agricultural areas were positively correlated with daily maximum temperature, heatwave days, and annual precipitation. However, agricultural land exhibited much stronger correlations than built-up areas, indicating that agricultural landscapes exert a greater influence on local climatic conditions because they occupy a much larger proportion of the study area. Agricultural land also showed a significant negative correlation with daily minimum temperature, suggesting greater diurnal temperature variation while remaining vulnerable to daytime heat stress. These findings imply that agricultural landscapes should be considered a priority in regional climate adaptation planning.

Wetlands demonstrated positive correlations with daily mean and minimum temperatures but negative correlations with daily maximum temperature and heatwave days, indicating their role in moderating daytime heat. Bare land exhibited a similar correlation pattern despite generally being associated with higher temperatures. This unexpected result is likely attributable to the small proportion of natural bare land, consisting mainly of sandy beaches and rocky shorelines, rather than

artificial exposed surfaces. Water surfaces showed no significant relationships with climatic variables, probably because the influence of the surrounding sea outweighed that of small inland water bodies.

Among all land-use types, forests and grasslands exhibited the strongest cooling function. They were the only land-use category showing a significant negative correlation with tropical night days, indicating that expanding forest cover could effectively reduce nighttime heat in coastal and island environments. Restoration of traditional village forests, together with improved management of secondary forests, therefore represents an effective nature-based adaptation strategy for enhancing local climate resilience.

Overall, the results demonstrate that land-use composition plays an important role in shaping local climatic conditions in coastal and island regions. Unlike conventional climate adaptation policies that primarily focus on urban environments, these findings emphasize the need for place-based nature-based solutions tailored to agricultural and island landscapes. Expanding green infrastructure through village forest restoration, conserving wetlands, and improving vegetation management can reduce heat stress while strengthening ecosystem resilience. Considering the high proportion of elderly residents and increasing climate vulnerability in coastal communities, these landscape-based adaptation measures should become an integral component of regional climate adaptation policies. Although this study was limited by differences in the observation periods of land-use and climate datasets and by the use of township-scale averaged data, it provides a useful scientific basis for developing localized climate adaptation strategies and highlights the need for finer-scale climatic monitoring in coastal and island regions.

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GIS-Based Spatial Assessment of Coastal Vulnerability to Multiple Hazards: Evidence from Ambon Island

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Abstract

This study aims to assess and map coastal vulnerability to earthquakes, tsunamis, coastal erosion, and flooding in Ambon Island. A quantitative-spatial approach based on Geographic Information Systems (GIS) was employed, using primary data from field observations, GPS surveys, documentation, interviews, and questionnaires, alongside secondary data, including population statistics, satellite imagery, digital elevation models, disaster maps, and spatial planning documents. Vulnerability was assessed across four dimensions: socio-cultural, economic, physical, and environmental/ecological, using scoring, weighting, and overlay analysis in ArcGIS. The results reveal variations in vulnerability across five districts. Nusaniwe scored 3.955 and Sirimau 3.900, both classified as highly vulnerable. Teluk Ambon (3.035) and Teluk Ambon Baguala (1.995) were classified as moderately vulnerable, while Leitimur Selatan (1.500) showed low vulnerability. Socio-cultural and economic vulnerability was high in Nusaniwe and Sirimau, whereas physical vulnerability was high in Sirimau, Teluk Ambon, and Teluk Ambon Baguala. Mangrove and seagrass ecosystem pressures, sedimentation, and coastal development require attention. Evacuation-route awareness was uneven: only 13.3% of respondents in Sirimau knew evacuation routes, compared with 80.9% in Teluk Ambon Baguala. These findings highlight the need for locally tailored mitigation, coastal spatial planning, ecosystem protection, and improved public risk communication and preparedness.

Keywords: coastal vulnerability; Geographic Information Systems (GIS); spatial analysis; multi-hazard disasters

Rethinking Island Agriculture: The Role of Agricultural Product Technology in Building Resilient and Sustainable Food Systems

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Abstract

Island food systems face geographic fragmentation, seasonal production, high transport costs and uneven postharvest infrastructure. Consequently, increased agricultural output does not necessarily ensure reliable access to safe, nutritious and affordable food. This conceptual paper examines how agricultural product technology can connect island agriculture with resilient and sustainable food systems, using Maluku, Indonesia, as an illustrative case. It synthesizes international literature and selected studies on sago, Tongka Langit banana, nutmeg, local tubers, gandaria and kenari. The analysis identifies commodity-specific opportunities in drying, milling, preservation, formulation and storage, while emphasizing that processing must be linked to quality assurance, viable value chains, market access and environmental stewardship. An integrated framework connects local resources, appropriate technologies, value-chain capabilities and food-system outcomes. Universities can support this process through research, training and collaborative technology transfer.

Keywords: Island agriculture; Food-system resilience; Agricultural product technology; Postharvest processing; Maluku, Indonesia

1. Introduction

Agriculture in island regions is shaped by more than farm output. Geographic fragmentation, limited cultivable land in some locations, seasonal harvests, uneven infrastructure and the cost of inter-island transport influence what food is available, where it can be obtained and at what price. Climate-related disruptions and dependence on external suppliers can intensify these constraints. Nevertheless, island regions also possess adaptive resources, including local knowledge, social networks, biodiversity and regional trade (Guell et al., 2022; Marrero and Mattei, 2022).

Food security therefore cannot be assessed through production growth alone. Food must be available, physically and economically accessible, nutritionally adequate and sufficiently stable over time. These outcomes emerge from interactions among production, processing, distribution, consumption, and environmental and institutional conditions (Ericksen, 2008; Tendall et al., 2015). Agricultural product technology, such as improved handling, drying, preservation, packaging and processing, can reduce avoidable losses, extend the usable life of seasonal crops and convert raw materials into ingredients for wider applications. However, technology does not guarantee resilience unless it is matched with local skills, operating costs, supply-chain coordination and market demand (Affognon et al., 2015; Spang et al., 2019).

This paper develops a conceptual perspective on the contribution of agricultural product technology to resilient and sustainable island food systems, using Maluku as an illustrative case. It synthesizes international literature and selected studies relevant to local commodities; it is neither a systematic review nor an impact evaluation. The central proposition is that technology is most useful when matched to local resources and capabilities and connected to quality assurance, markets, community participation and environmental performance.

2. Island agriculture and food-system resilience

In archipelagic settings, farms, processing facilities, ports, markets and technical services may be located on different islands. Weather and transport schedules affect delivery time and cost, while dispersed production can make raw-material aggregation and regular supply difficult. Postharvest

damage, heat and moisture exposure, inadequate packaging and transport delays further reduce marketable quantity and quality. These challenges do not mean that islands should pursue complete self-sufficiency: local production, inter-island exchange, imports and reserves can complement one another, while overdependence on a narrow set of supply routes can increase exposure to disruption (Chin et al., 2024; Marrero and Mattei, 2022).

Food-system resilience concerns the capacity to continue providing sufficient, appropriate and accessible food despite disturbances. In this paper, five operational dimensions are considered: availability (food is present), accessibility (physical and economic access), nutrition (dietary quality and safety), stability (continuity through time and shocks) and adaptability (the capacity of actors and institutions to learn and adjust). These dimensions are interdependent and should be considered alongside sustainability and the ability of people to shape food systems (Tendall et al., 2015; Clapp et al., 2022).

3. Maluku's resources and illustrative technology pathways

Maluku's agricultural biodiversity offers different routes to value creation rather than one universal processing model. Sago (Metroxylon sagu) and local tubers are sources of starch-rich ingredients; Tongka Langit banana (Musa troglodytarum) and gandaria (Bouea macrophylla) are perishable fruits; nutmeg (Myristica fragrans) has established spice markets and potential for selected product diversification; and kenari (*Canarium indicum*) is a distinctive nut ingredient whose storage quality requires attention. These resources can support dietary variety and local value creation, but benefits depend on production diversity, appropriate processing and market access (Jones, 2017; Renard and Tilman, 2021).

Table 1. Illustrative agricultural product technology pathways for Maluku

Local resource	Potential technology	Potential contribution
Sago and local tubers	Flour and starch production; composite ingredients	More varied, storable ingredients and additional food applications
Tongka Langit banana	Controlled drying, flour production and product formulation	Less dependence on immediate fresh-fruit sales; new product options
Nutmeg	Improved drying and grading; suitable product diversification	Potential added value and greater use of selected raw-material fractions
Gandaria	Appropriate preservation and fruit processing	Potential reduction of avoidable losses and differentiated fruit products
Kenari	Kernel processing, moisture management and oxidation control	Improved storage quality and diversified ingredient uses

Source: Authors' synthesis based on Karim et al. (2008), Pratiwi and Krisbianto (2019), Timisela et al. (2021), Breemer and Pattiruhu (2023), Palijama et al. (2024), and Walton et al. (2017).

The pathways in Table 1 are opportunities for targeted development and evaluation, not claims that all products are already commercialized at scale in Maluku. Their feasibility is affected by seasonal supply, processing facilities, technical skills, maintenance, finance, energy and water availability, product safety, packaging, shelf-life control, transport costs and market information. Sago development, for example, requires attention to processing efficiency, water use, consistency and residue management, as well as facilities, marketing and coordination (Karim et al., 2008; Timisela et al., 2021). Tongka Langit banana flour has been characterized for nutrient content, beta-carotene and antioxidant activity, but product performance depends on maturity, pretreatment, drying, storage and formulation (Pratiwi and Krisbianto, 2019). Nutmeg diversification, gandaria processing and kenari storage likewise require product- and market-specific evaluation (Breemer and Pattiruhu, 2023; Palijama et al., 2024; Walton et al., 2017).

4. Connecting product technology with resilient food systems

Appropriate handling, drying, storage, packaging and preservation can increase the share of harvested food that remains usable and extend the period in which selected products can be marketed or consumed. Processing can also convert raw materials into ingredients with different storage properties and uses. Yet reduced loss or longer shelf life should not be inferred from equipment installation alone. Evaluation should span the supply chain and use indicators such as processing yield and loss, moisture, relevant microbial safety, nutrient or quality retention, packaging performance, shelf life, unit cost and consumer acceptance (Affognon et al., 2015; Spang et al., 2019).

Technology selection should be based on four connected tests: (i) technical feasibility with available raw materials, equipment, skills, utilities and maintenance; (ii) consumer and market acceptance, including taste, convenience, price, safety and intended use; (iii) economic viability, accounting for investment, operation, labour, packaging, transport and maintenance; and (iv) environmental performance, considering water, energy, packaging and by-products. A centralized facility may suit locations where supply can be aggregated and transport is dependable, whereas decentralized processing may be more appropriate for perishable raw materials or remote communities. The most sophisticated machine is not necessarily the most appropriate: maintainability, operator confidence, product quality and lifetime costs matter.

LOCAL RESOURCES	**APPROPRIATE TECHNOLOGY**	**PRODUCT & VALUE CHAIN**	**FOOD-SYSTEM OUTCOMES**
Local crops, seasonal supply and traditional knowledge	Handling, preservation, drying, milling, formulation and packaging	Quality, food safety, shelf life, cost control and market access	Availability, accessibility, nutrition, stability and adaptability
CROSS-CUTTING ENABLERS: research and extension | community participation | infrastructure and finance | institutional coordination | consumer acceptance | environmental stewardship			

Figure 1. Integrated pathway from local resources to island food-system resilience

The framework is a conceptual proposition, not a validated causal model. It links the local resource base to context-appropriate technology and the capabilities needed to produce dependable products, then to food-system outcomes. Outcomes depend on adoption and performance rather than technology alone. Monitoring should therefore consider technical output, supply reliability, affordability, nutritional quality where relevant, enterprise performance and resource efficiency. Evidence on product quality, costs, demand and environmental performance should feed back into process design and investment decisions.

5. Universities and regional partnerships

Universities can bridge locally available agricultural resources with technologies, quality systems and market relationships. Their contribution can include raw-material characterization, process development and optimization, product formulation, shelf-life and food-safety evaluation, sensory testing, training and support for quality-control procedures. Knowledge transfer involves relationships and the ability to adapt knowledge to practical settings, not simply the delivery of a finished invention (Tolin and Piccaluga, 2024). In Maluku, Universitas Pattimura can work with producers, processors, government and community organizations to evaluate local flours, develop appropriate preservation processes, train operators and study consumer acceptance and product economics. Such partnerships should be shaped by community capability and demand. Their outcomes should be assessed through

documented adoption, product quality, enterprise continuity, income distribution and food access, rather than assumed from demonstrations or research activity alone.

6. Conclusion

Maluku's sago, Tongka Langit banana, nutmeg, local tubers, gandaria and kenari offer distinct opportunities for value creation, but local resource availability does not automatically ensure access to safe, nutritious and affordable food. Agricultural product technology can strengthen island food systems by reducing avoidable losses, extending the useful life of selected commodities, diversifying ingredients and supporting local enterprises. These contributions are more likely to endure when processing is connected to aggregation, quality assurance, distribution, consumer acceptance, environmental performance and regional partnerships. An integrated approach that matches local resources with appropriate technologies, capable value chains and supportive institutions can advance food availability, accessibility, nutrition, stability and adaptability together. Future work should test the proposed framework through commodity-specific studies of technical performance, economic feasibility, consumer response, environmental implications and the distribution of benefits across Maluku's island communities.

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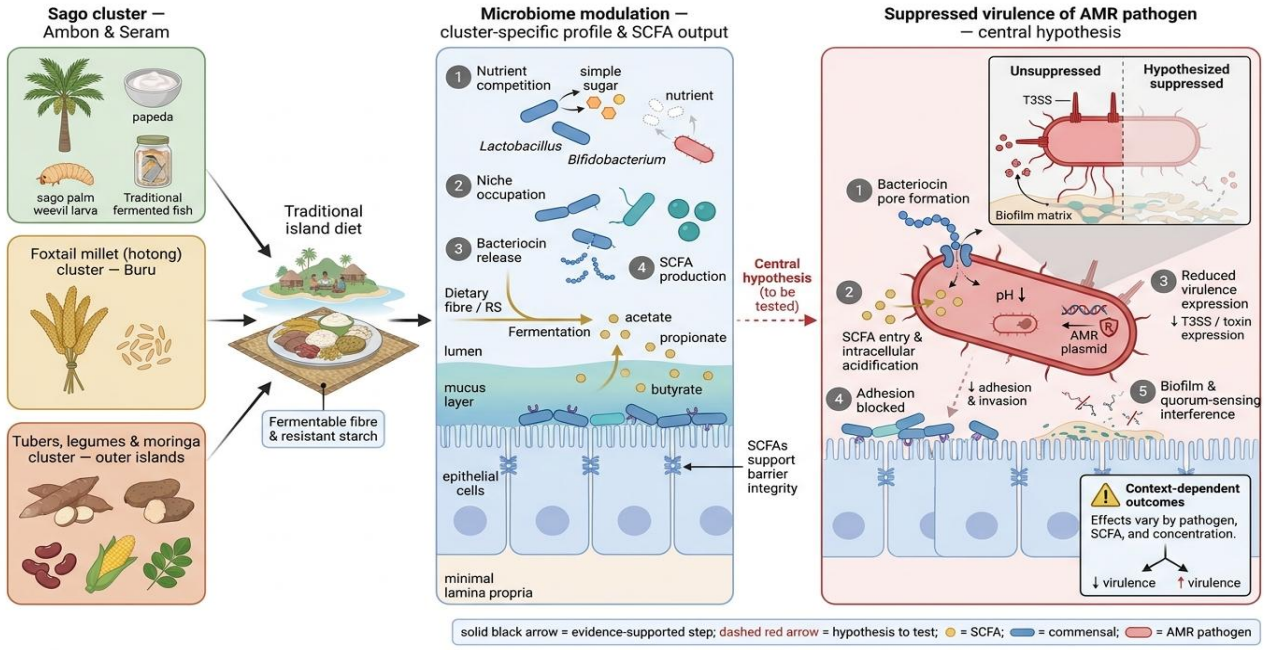
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Can Maluku's Traditional Foods Modulate Microbiome Function and AMR Pathogen Virulence? Exploring the Future Value of Island Food Resources for Sustainable Health

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Graphical Abstract



The graphical abstract proposed conceptual framework evaluating whether habitual consumption of traditional staple food across Maluku Province may modulates human gut microbiome composition and exert selective antivirulence pressure on antimicrobial-resistant (AMR) pathogens. Solid arrows indicate relationships supported by published evidence (diet shapes microbiome composition and metabolite output); dashed arrows indicate the central hypothesis to be tested (cluster-specific microbial functions – nutrient and niche competition, bacteriocins, and SCFAs – may pressure AMR pathogen colonization, adhesion, virulence expression, and resistome).

1. Background and Rationale

Antimicrobial resistance (AMR) is increasingly recognized as an ecological problem, rather than one restricted to clinical settings. The gut microbiome acts as a major reservoir of antibiotic resistance genes (ARGs) and mobile genetic elements (MGEs), facilitating horizontal gene transfer among commensal microflora and opportunistic pathogens. Therefore, microbiome-directed dietary interventions offer a biologically plausible, non-bactericidal strategy to complement antibiotic stewardship[1]. While predominant studies have focused on pathogen adaptation to bactericidal agents or host immune responses, this concept explores a complementary perspective: can the dietary and microbial environment shaped by traditional food resources able to suppress AMR pathogens and modulate their interactions?

Antivirulence strategies are known to effectively reveal selective pressure for expression of type III secretion systems (T3SS), adhesion molecules, and toxin production which is crucial resistance mode among AMR pathogens[2]. Microbial metabolites, particularly short-chain fatty acids (SCFAs) such as acetate, propionate, and butyrate, represent powerful natural modulators of bacterial gene expression[3]. Diet is well established as a primary determinant of gut microbiome composition, metabolic output, and resistome architecture throughout life[4,5]. Maluku, an archipelagic province characterized by distinct

staple food geography across short oceanic distances, offers an unparalleled natural laboratory to investigate the interplay between localized dietary exposures, microbial ecology, and pathogen pressure.

2. Maluku's Food Geography: Three Dietary Clusters

This framework proposed three distinct dietary clusters aligned with documented regional food geography, agroecological systems, and cultural practices across the archipelago. To understand the dietary patterns, three clusters were proposed based on dominant traditional staple exposure:

Cluster	Island	Dominant traditional foods	Key microflora and substrates
I	Ambon, Seram, and Central Maluku (Teon, Nila, Serua)	Sago (*Metroxylon sagu*) and its differentiated products (papeda, sinoli, sagu tumbu); sago grub (*Rhynchophorus ferrugineus*; Inasua (traditional fermented fish)	Resistant Starch Type III (RS3); insect protein, chitin and omega-3; Lactic Acid Bacteria (*L. plantarum*, *L. rhamnosus, L. paracasei, Leuconostoc mesenteroides*) [6–9]
II	Buru	Hotong (*Setaria italica*, foxtail millet)	Foxtail millet RS3, polyphenols, plant protein, complex fiber, Fe and Zn. [10]
III	Kei, Tanimbar, Aru, and Southwest Maluku	Tubers: enbal (bitter cassava, *Manihot esculenta*), gembili (*Dioscorea esculenta*), kentang hitam (*Plectranthus rotundifolius*), gayong (*Canna edulis*); legumes; corn; moringa (*Moringa oleifera*) leaves	Cyanogenic-detoxified cassava RS, inulin and fructooligosaccharides, Canna RS3 (propionate/valerate driver), moringa polyphenols. [11–13]

This clustering reflects documented food geography: sago remains the cultural and caloric anchor of central Maluku, cassava-based enbal serves as the staple of the Kei Islands where traditional hydraulic pressing and drying detoxify bitter cassava, and hotong grain constitutes the endemic dryland staple of Buru Island. Importantly, this dietary transition is under severe pressure due to ongoing rice substitution policies and shifting consumer habits, giving this framework double urgency for both public health resilience and regional food sovereignty.

3. Prebiotic and Probiotic Potential of the Cluster Foods

A strict terminology applies: a *probiotic* requires a demonstrated health benefit from a live, adequately dosed microorganism, whereas most of these foods are better described as candidate *prebiotic* substrates or candidate beneficial strains awaiting characterization[14]. With this caution, the published evidence supports the biological plausibility of every cluster.

Cluster I: Sago, Sago Grub, and Inasua Fermentation

Sago starch (*Metroxylon sagu*) yields high concentrations of Resistant Starch Type III (RS3). In vitro fecal fermentation demonstrates that sago RS3 achieves a Prebiotic Index (PI) of +12.19, surpassing commercial fructooligosaccharides (+9.45) and inulin (+6.82) by selectively stimulating Bifidobacteria and Lactobacilli while suppressing Bacteroides, Clostridia, and Enterobacteriaceae[15,16]. Sago grubs (*Rhynchophorus ferrugineus*) provide a rich protein exposure (28% crude protein containing all 9 essential amino acids), chitin polysaccharides, and polyunsaturated fatty acids that act as fermentable substrates for mucosal microflora[17–19]. Moreover, the traditional fermented fish inasua, processed with salt and coconut sap by TNS communities in Central Maluku, harbors a dynamic succession of lactic acid bacteria, predominantly *Lactobacillus plantarum* (e.g., strain ITN13/IN05), *L. rhamnosus* (strain IN13),

L. paracasei (IN17), and *Leuconostoc mesenteroides* (ITN17). Strains such as *L. rhamnosus* IN13 and *L. plantarum* IN05 produce potent bacteriocins with documented inhibitory activity against pathogenic *Salmonella typhimurium* and *Listeria monocytogenes*[9].

Cluster II: Hotong

Hotong (*Setaria italica*) is an agroecologically resilient dryland cereal cultivated by local communities in Buru Island (e.g., Namrole District, South Buru Regency). Proximate evaluation of Buru hotong reveals a high nutritional density: 11.60% crude protein, 65.31% complex carbohydrates, 3.43% fat, 2.20% crude fiber, 4.8 mg/100g iron (Fe), and 2.7 mg/100g zinc (Zn)[10]. In South Buru, where toddler stunting prevalence reaches 35.5% (exceeding the national average of 21.6%), hotong can contribute up to 40% of daily protein and 35% of iron requirements for children aged 1–3 years [10]. Beyond primary nutrition, modulates gut microbiota composition and alleviates metabolic disease in mouse models[20], millet-bran polyphenols remodel the gut microbiome and restore barrier function in colitis models[21], and millet-resistant starch and phenolics are consistently associated with SCFA-producing taxa[22].

Cluster III: Tubers, legumes, corn, and moringa

Gembili tubers are a documented source of inulin and prebiotic oligosaccharides that stimulate *Bifidobacterium* and *Lactobacillus* in fecal fermentation[11]. *Canna edulis* (gayong) RS3 resists digestion, is fermented by human gut microbiota with increased propionic and valeric acids, and improves metabolic and inflammatory markers in animal models[23,24]. Hausa potato (kentang hitam) has comparatively high protein and fiber content among tubers. Bitter cassava, the basis of enbal, contributes resistant starch, and modified cassava starch supports the growth of probiotic *Lactobacillus* strains. Legumes are rich sources of resistant starch that modulate the gut microbiome[25]. Complementing these starches, *Moringa oleifera* leaf polyphenols and fibers act as candidate prebiotics, as it metabolized by gut microbes and stimulating bifidobacteria in vitro[26].

4. Central Hypothesis and Conceptual Model

Central Hypothesis: Habitual consumption of cluster-specific traditional foods generates distinct gut microbiome profiles and metabolite milieux that exert differential selective pressure on AMR pathogens, reducing their colonization, suppressing virulence expression, and limiting ARG dissemination.

The methodological foundation for testing this hypothesis could be derived from literature. Deep metagenomic analysis of Indonesian populations has shown that geography and community lifestyle are key determinants of gut microbiome composition, with measurable structures from village to village[27] and subsistence-lifestyle populations in neighboring Papua New Guinea carry distinct gut microbiota[28].

Accordingly, three distinct biological classes underpin the hypothesis:

- **Colonization Resistance:** Substrate-adapted commensal microflora competitively excludes incoming AMR pathogens through nutrient niche competition, occupation of mucosal binding sites (blocking adhesion), and secretion of anti-competitor molecules, including LAB bacteriocins (e.g., *L. rhamnosus* IN13 bacteriocins active against Salmonella and Listeria) [29,30].
- **Metabolic Repression of Virulence:** Microbiota-derived SCFAs (acetate, propionate, butyrate) repress pathogen virulence expression. For example, SCFAs suppress the Salmonella Type III Secretion System (T3SS-1) by slowing the growth rate of virulence-expressing subpopulations, downregulating invasion genes, and lowering intracellular bacterial pH [31,32].
- **Resistome Constriction:** High-fiber, complex carbohydrate diets promote saccharolytic commensals at the expense of ARG-rich Proteobacteria, resulting in a lower overall gut antibiotic resistome burden and reduced mobile [3–5].

5. Proposed Experimental Roadmap

To rigorously test this framework within Maluku Province, a prospective three-phase experimental roadmap is proposed:

Phase & Timeline	Focus Area	Methodology & Key Deliverables
Phase 1: Discovery	Cross-sectional survey	Cluster-stratified sampling per cluster across Ambon/Seram (Cluster I), South Buru (Cluster II), and Kei-Tanimbar-Kisar (Cluster III). Dietary recall instruments adapted to Maluku foods; stool 16S rRNA and shotgun metagenomics; targeted metabolomics (SCFAs, bile acids); resistome profiling (ARG abundance and MGE context).
Phase 2: Function	*in vitro* fermentation and antivirulence assays	In vitro batch fermentation of Maluku cluster preparations (sago RS3, hotong flour, enbal starch, gembili inulin) using local human fecal inocula. Supernatant testing against clinical AMR isolates (Salmonella, *E. coli*, *S. aureus*) assessing epithelial adhesion, invasion, biofilm formation, and T3SS gene expression.
Phase 3: Validation	*in vivo* models and LAB characterization	Host-cell infection and animal models evaluating pathogen colonization resistance under cluster diet regimens. Safety, genomic, and bacteriocin characterization of Inasua LAB strains for functional food starter development.

6. Significance for Archipelagic Sustainability and Regional Health

This research framework directly aligns with regional health and agricultural priorities in Maluku Province. By establishing scientific evidence for the gut health and antivirulence benefits of sago, hotong, enbal, and gembili, the program repositions indigenous island food heritage as a critical scientific asset. It strengthens the rationale for preserving local agricultural biodiversity against rice monoculture, provides an evidence-based approach to address severe child stunting in South Buru, and positions Maluku as a pioneer in archipelagic AMR mitigation.

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Climate Resilience Based on Traditional Knowledge in the *Gudeuljang* Rice Terraces of *Cheongsando*

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Abstract

This study examines the climate resilience of the *Gudeuljang* rice terraces on *Cheongsando* Island, Republic of Korea, through the perspectives of traditional ecological knowledge, community-based management, and agricultural heritage care. Constructed with stone walls, soil, and irrigation systems on steep slopes, the terraces reflect local adaptations to limited land and water resources. Drawing on literature, policy documents, and comparative insights from the Ifugao Rice Terraces, this study finds that resilience depends not only on physical structures but also on continuous cultivation, collective maintenance, and intergenerational knowledge transmission. Stone walls and terraced fields can reduce soil erosion, regulate water flow, and stabilize slopes. However, climate hazards, rural ageing, population decline, farmland abandonment, and the weakening of traditional knowledge threaten their sustainability. The study argues for an integrated approach linking climate-adaptive maintenance, resident participation, ecological conservation, local livelihoods, and long-term governance.

Keywords: *Gudeuljang* Rice Terraces; Climate Resilience; Traditional Ecological Knowledge; Agricultural Heritage; Community-Based Management

1. Introduction

Climate change poses complex threats to agricultural landscapes and local communities in island regions. Changes in the frequency and intensity of heavy rainfall and droughts, as well as risks associated with typhoons, landslides, soil erosion, and water insecurity, are major factors undermining the sustainability of hillside agriculture and small-scale agroecosystems. Traditional agricultural landscapes, in particular, are the outcomes of long-term accumulations of local environmental knowledge, livelihood techniques, community norms, and intergenerational knowledge transmission. Therefore, climate change threatens not only the physical integrity of these landscapes but also the cultural memory, livelihood foundations, and social reproduction of local communities.

The *Gudeuljang* rice terraces of *Cheongsando* Island, located in Wando County, Jeollanam-do, Republic of Korea, constitute a traditional agricultural landscape created by constructing stone walls on sloping land, covering them with soil, retaining water, and cultivating rice. Developed in response to the geographic constraints of an island environment—including limited flat land, scarce water resources, and steep slopes—the *Gudeuljang* rice terraces embody locally adapted knowledge of stone-wall construction, soil formation, water management, and hillside cultivation. Recognized as Korea's first Nationally Important Agricultural Heritage System and as a Globally Important Agricultural Heritage System, the *Gudeuljang* rice terraces possess considerable heritage value. However, they are increasingly confronted by rural ageing, population decline, farmland abandonment, shortages of maintenance labor, and heightened climate-related disaster risks.

Recent heritage scholarship has increasingly approached heritage not simply as an object to be preserved, but as a practice of carethat sustains relationships among people, ecosystems, memories, and livelihoods, while responsibly transmitting them to future generations. This perspective is clearly illustrated by the case of the Ifugao Rice Terraces in the Philippine Cordilleras. The Ifugao community recognizes traditional ecological knowledge, intergenerational responsibility, community solidarity, and the sustainable management of land and resources as essential assets for responding to climate change. This case suggests that the *Gudeuljang* rice terraces of *Cheongsando* should likewise be examined not merely in terms of the preservation of traditional farming techniques, but also in relation

to local adaptive capacity and integrated heritage-management systems. The purpose of this study is to examine the traditional knowledge and management practices embedded in the *Gudeuljang* rice terraces of *Cheongsando* and to explore their potential and limitations as resources for agricultural-heritage resilience in the context of climate change.

2. Materials and Methods

2.1 Study Area

This study focuses on the *Gudeuljang* rice terraces distributed across *Cheongsando* Island in Wando County, Jeollanam-do, Republic of Korea. The *Gudeuljang* rice terraces are a traditional terraced-rice landscape formed by building stone walls along slopes, covering them with soil, and creating irrigated paddies. They represent environmentally adaptive agricultural knowledge developed by island residents to use limited arable land and water resources efficiently. The study defines the research subject not only as the rice paddies themselves but also as an agricultural, ecological, and cultural landscape encompassing stone walls, irrigation channels, surrounding forests and villages, cultivators and local organizations, and livelihood practices associated with farming.

2.2 Research Methods

This study employs a qualitative case-study approach. The research materials are organized as follows.

First, this study reviews the agricultural heritage designation documents and management plans related to the *Gudeuljang* rice terraces of *Cheongsando*. It also conducts semi-structured interviews with terrace cultivators, village residents, local government officials, agricultural heritage interpreters, and relevant experts. The interviews examine the transmission of traditional agricultural techniques; water management and stone-wall maintenance; perceptions and experiences of climate change and disasters; practices of collective labor and resident participation; and changes in conservation and utilization policies.

Second, domestic and international literature on climate change, agricultural heritage, traditional ecological knowledge, community-based adaptation, and heritage care is analyzed. In particular, the climate vulnerability assessment of the Ifugao Rice Terraces in the Philippine Cordilleras is used as a comparative reference to examine the relationship between traditional knowledge, intergenerational responsibility, community solidarity, ecological management, and climate resilience.

3. Results

3.1 Traditional Agricultural Techniques Adapted to Environmental Condition

The literature review indicates that the *Gudeuljang* rice terraces of *Cheongsando* can be understood as an environmentally adaptive agricultural system combining stone-wall construction, soil formation, and hillside cultivation. The construction of stone retaining walls to define the boundaries of rice paddies constituted a practical response to the need to secure cultivable land and reduce soil loss on steep slopes. These structures function not merely as scenic elements but as essential infrastructure that supports land stability, water retention, soil conservation, and the continuity of agricultural activity.

In addition, the *Gudeuljang* rice terraces developed as a means of subdividing and cultivating small plots of land in an island environment with limited flat terrain. This practice demonstrates traditional ecological knowledge based on the restrained use of land and water resources in accordance with topographic conditions, rather than on their excessive exploitation.

3.2 Climate-Adaptation Potential of Stone Walls, Soil, and Water Management

The stone walls and terraced structure of the *Gudeuljang* rice terraces may contribute to reducing the risks of soil erosion and slope failure by dispersing water and sediment flows during periods of heavy rainfall. The stepped arrangement of paddies, stone walls, and irrigation channels regulates the movement of water in stages and helps reduce rapid water loss.

However, this resilience cannot be sustained automatically by the physical structures alone. Cracks or collapses in stone walls, blocked irrigation channels, and the spread of weeds and woody vegetation resulting from farmland abandonment may weaken the stability of the entire terrace system. Thus, the adaptive potential of traditional techniques can become actual resilience only when supported by regular maintenance, continued cultivation, and the management capacity of local residents.

3.3 Community-Based Management and Heritage as Care

The maintenance of the *Gudeuljang* rice terraces has likely depended not only on the labor of individual farming households but also on village-level cooperation, shared practices for managing waterways and stone walls, and mutual assistance during the agricultural season. Such community-based management encourages the recognition of agricultural heritage not merely as private property or a tourism resource, but as a shared foundation of life that residents must collectively sustain and transmit to future generations.

In this context, the *Gudeuljang* rice terraces can be reinterpreted through the concept of heritage as care. In other words, the sustainability of the terraces depends not simply on preserving their physical form, but on maintaining the interconnections among residents' farming practices, community relationships, ecological stewardship, and the transmission of local knowledge and skills.

3.4 Complex Vulnerabilities Resulting from Climate, Demographic, and Economic Change

The *Gudeuljang* rice terraces are exposed simultaneously to climate-related risks—including heavy rainfall, drought, typhoons, and soil erosion—and to socioeconomic risks such as rural ageing, population decline, farmland abandonment, and the weakening transmission of traditional techniques. In particular, the cessation of farming can lead not only to the deterioration of paddy fields but also to a reduction in the labor force needed to care for stone walls and irrigation facilities.

Even if the tourism value of agricultural heritage increases, the management base of the terraces may remain fragile unless economic benefits are sufficiently returned to cultivators and local residents. Therefore, an increase in visitor numbers or landscape promotion alone cannot guarantee sustainability. Practical support for agricultural activity, local livelihoods, and maintenance labor must accompany heritage-tourism initiatives.

4. Discussion

The climate resilience of the *Gudeuljang* rice terraces cannot be explained solely by traditional stone-wall construction techniques or by the physical structure of terraced paddies. Rather, it is a socioecological capacity formed through the integration of long-term environmental observation, restrained land and water use, community mutual aid, continuous cultivation and repair work, and intergenerational knowledge transmission. This perspective is closely related to the significance of traditional knowledge and community solidarity observed in the Ifugao Rice Terraces.

Whereas the Ifugao concept of tawid(binoltan) emphasizes the intergenerational responsibility to transmit inherited heritage to future generations, the *Gudeuljang* rice terraces may likewise be understood as heritage requiring the transmission not only of the landscape itself but also of agricultural techniques, everyday knowledge, and responsibilities for maintenance. Similarly, if the Ifugao concept of tanud encompasses ecological balance, food production, and economic opportunity, the *Gudeuljang* rice terraces should also be regarded as a multi-dimensional resource connected to local food systems, environmentally friendly agriculture, education, cultural tourism, and local employment.

Nevertheless, the two cases should not be treated as identical. The Ifugao Rice Terraces are based on a large-scale mountain agricultural landscape and the governance of an Indigenous community, whereas the *Gudeuljang* rice terraces of *Cheongsando* developed within the context of small-scale hillside farming and changing rural society on Korea's southern islands. Policies for *Cheongsando* should

therefore not simply replicate external examples; instead, they must reflect local conditions, including demographic structure, landownership relations, farming scale, the tourism economy, administrative systems, and the capacities of community organizations.

5. Conclusion

This study interprets the *Gudeuljang* rice terraces of *Cheongsando* as both a traditional agricultural-technology heritage and a socioecological resource for resilience in the era of climate change. The terraces embody knowledge of stone-wall construction, soil formation, water management, and small-scale cultivation that developed in response to the environmental conditions of an island characterized by steep slopes and limited water resources. Such knowledge has the potential to address climate-related risks, including heavy rainfall, soil erosion, and drought, and can function more effectively when combined with continuous community management and cooperation.

However, population decline, rural ageing, farmland abandonment, the disruption of traditional knowledge transmission, and increasing climate hazards are weakening the foundations for maintaining the *Gudeuljang* rice terraces. Accordingly, conservation should not be confined to preserving the external appearance of the landscape or promoting it as a tourism resource. A long-term management system is required that integrates residents' livelihoods and participation, intergenerational transmission of traditional knowledge, climate-adaptive management of stone walls and irrigation systems, local economic circulation, and ecological conservation.

In conclusion, the *Gudeuljang* rice terraces of *Cheongsando* are not merely remnants of past agricultural techniques; they are the product of long-term relationships of care between people and nature. Agricultural-heritage policy in the age of climate change must therefore move beyond protecting heritage itself and instead sustain the people, communities, ecosystems, and local economies capable of caring for that heritage.

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From Rock to Sand: AI-Based Cultural Translation of the Mountain–River–Sea Material Genealogy in the Shuangxi–Fulong Region, Taiwan

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This study examines the Shuangxi–Fulong region in northeastern Taiwan through the material transformation chain from rock to sand, exploring how flows among mountains, rivers, and the sea shape local landscapes, cultural memory, and design resources. While Shuangxi is defined by mountain settlements, river systems, the Tamsui–Kavalan Trails, mining relics, and agricultural heritage, Fulong is renowned for its estuary, beaches, and coastal tourism. Despite these distinctions, the two areas form a continuous mountain–river–sea cultural route, interconnected by geological weathering, fluvial transportation, and coastal deposition. Integrating design anthropology, material culture studies, local cultural translation, and generative AI, this research first analyzes documents, field observations, visual records, and cultural assets related to the rock-to-sand transformation. Subsequently, it constructs an AI-assisted cultural translation database utilizing semantic tagging, relational classification, visual feature analysis, and prompt generation. Developed on the Dify platform, the proposed prototype integrates a local knowledge base, Retrieval-Augmented Generation (RAG), prompt workflows, and large language models to generate keywords, local narratives, cultural interpretations, and design prompts. The outcomes support the creation of cultural route maps, infographics, material translation cards, and local product concepts, contributing to sustainable cultural tourism, regional revitalization, and the future value of island regions.

Keywords: Mountain–river–sea, Material genealogy, Local cultural translation, Generative AI, Design ideation.

Where Ecological Value Meets Customary Tenure: Rationale and Socio-spatial Considerations for Zoning the Banda Sea Large-Scale Marine Protected Area, Maluku, Indonesia

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Abstract.

Indonesia is developing a Large-Scale Marine Protected Area (LSMPA) of about 11.2 million ha in the Banda Sea (FMA 714) under its 30x45 MPA vision. This paper sets out the ecological rationale for the LSMPA and argues that customary marine tenure must be mapped before zones are drawn. The Banda Sea channels the Indonesian Throughflow, has seasonal upwelling, spans habitats from reefs to deep basins, and is core habitat for pygmy blue whales, whale sharks and tuna. A mixed-methods study in 21 villages (428 fishers, 159 fish traders, focus groups, interviews and participatory mapping) found that fishing is the main income for 93.7% of fishers and that 54.2% have no alternative income. Customary claims (petuanan) and sasi persist, and fishing grounds of at least seven villages lie inside or next to the indicative boundary, mostly for tuna. Because the species that justify the LSMPA are the same species on which communities depend, in the same places, a tenure-first zoning approach is proposed.

Keywords: large-scale marine protected area, Banda Sea, customary marine tenure, sasi, participatory mapping, small-scale fisheries

1. Introduction

Indonesia aims to protect 30% of its coastal and marine area, about 97.5 million ha, by 2045 (MPA Vision 30x45). In September 2026, Konservasi Indonesia submitted an initiative proposal to the Ministry of Marine Affairs and Fisheries for an LSMPA in the Banda Sea (YKCI, 2026). The indicative area of about 11.2 million ha lies within the Fisheries Management Area (FMA) 714, Maluku Province, and is bounded by 53 points between southern Buru and the Kei Islands (Figure 1). Zoning is planned for October 2026 to February 2027, and designation for June 2027.

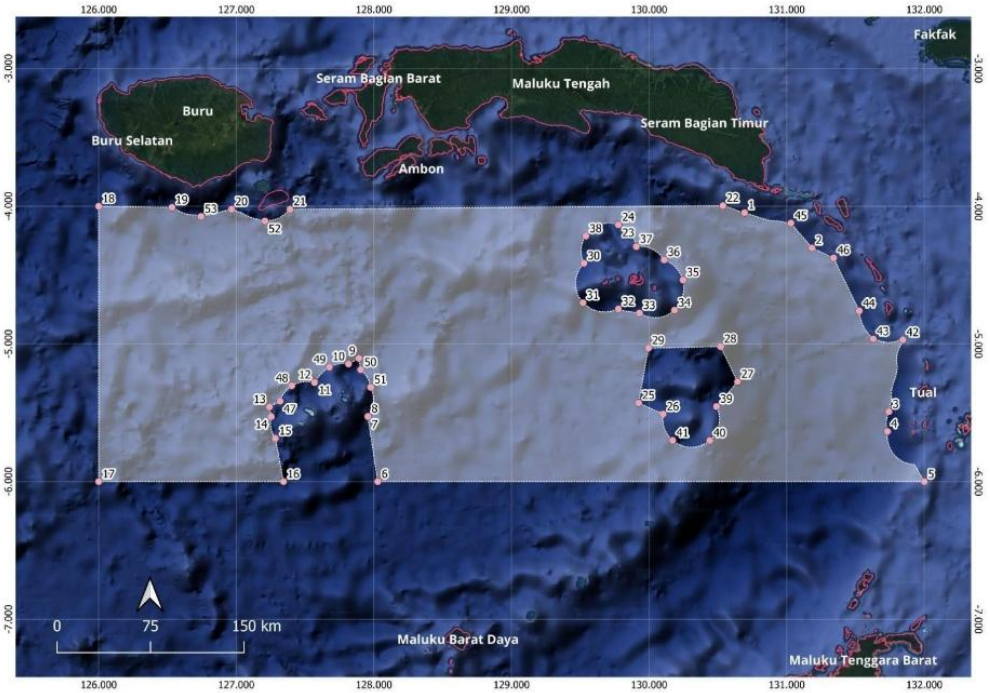


Figure 1. Indicative boundary of the proposed Banda Sea LSMPA (shaded; 53 boundary points), about 11.2 million ha within FMA 714. Source: YKCI (2026).

LSMPAs protect connected habitats, wide-ranging species and ecological processes at scales that small coastal MPAs cannot capture (Nikitine et al., 2018). Their outcomes for people, however, depend on how local users are included (Baker et al., 2025). Many communities around the Banda Sea hold customary sea rights (petuanan) and regulate harvests through sasi, a temporary closure enforced by customary institutions (Harkes and Novaczek, 2002). This paper (1) presents the ecological rationale for the LSMPA, (2) identifies where customary tenure and livelihoods meet the boundary, and (3) draws implications for zoning.

2. Why the Banda Sea matters

The value of the Banda Sea lies in links between habitats, species and oceanographic processes that operate across the basin and beyond existing MPA boundaries (YKCI, 2026).

Oceanography. The Banda Sea is a main pathway of the Indonesian Throughflow, with an inflow of about 6.27 ± 3.81 Sv that is strongest at 50–150 m depth (Giu et al., 2020). Monsoon-driven upwelling from April to October, peaking in August, raises chlorophyll-a and supports the food web (Tristianto et al., 2021).

Habitats and biodiversity. Habitats range from reefs of the Banda Islands, with 397 recorded coral species, and mesophotic reefs at 84–134 m, with more than 100 fish species (Limmon, 2026), to seamounts, the Weber Deep and deep basins that hold at least 44 echinoderm species (Setyastuti and Wirawati, 2018).

Migratory megafauna. Satellite tracking identifies the Banda Sea as an important foraging and resting area for pygmy blue whales, which spent up to about 124 days in Indonesian waters (Thums et al., 2022), and as seasonal migration and foraging habitat for whale sharks (Putra et al., 2026).

Fisheries under pressure. FMA 714 has a total allowable catch of 697,730 t (MMAF, 2022). Tuna larvae occur in the Banda Sea (Romdon et al., 2019), yet fishing mortality of yellowfin tuna exceeds natural mortality (Damora and Baihaqi, 2013), and juveniles made up about 70% of the skipjack catch in 2019–2024 (Nur et al., 2025).

These values define three groups of conservation targets: tuna and threatened megafauna; deep-sea, seamount and pelagic habitats; and the processes of larval dispersal, migratory connectivity and upwelling (YKCI, 2026).

3. Methods

The ecological rationale was synthesised from the initiative proposal, which compiled published studies and data presented at the Banda Sea LSMPA symposium in Ambon in January 2026 (YKCI, 2026). The social study was conducted from April to September 2026 by Universitas Pattimura with Konservasi Indonesia in 21 villages across 8 island clusters (Banda, Buru, Ambon, Lease, South Seram, East Seram, Kei and Southwest Maluku), after Free, Prior and Informed Consent was obtained from customary leaders. It combined a household survey of 428 fishers and 159 fish traders (papalele), focus groups on sea boundaries and access rules, interviews with the Raja and kewang (customary marine wardens), and participatory mapping that was digitised and overlaid on the indicative boundary. Survey data were analysed with descriptive statistics, chi-square tests (Cramér's V) and Multiple Correspondence Analysis. Overlap with the boundary was assessed visually and has not yet been quantified.

4. Results

Livelihoods depend heavily and seasonally on the sea. Fishing was the main income for 93.7% of fishers, and 54.2% had no other income. In the peak season 41.8% earned more than IDR 4 million per month, but in the lean season 48.6% earned less than IDR 1 million. Gear is mainly selective and small-

scale, led by hand lines (342 respondents). Most fishers (61.9%) and papalele (86.2%) reported declining catches or sales over 20 years. Village was the strongest predictor of socio-economic conditions (Cramér's V up to 0.88), outweighing individual attributes.

Customary tenure and fishing grounds meet the boundary. Negeri Latuhalat holds customary rights over the Lucipara Islands, and the Teon–Nila–Serua community, now living in Waipia on Seram, retains petuanan over its home islands. Marine sasi for trochus, sea cucumber and lobster continues in Nolloth, Waipia, Yamtel, Tehoru and Kampung Baru, though in Nolloth it was last held in 2020. Fishing grounds of at least seven villages lie inside or next to the boundary, mostly for tuna (Table 1, Figure 2). The boundary already excludes the Banda and Lucipara Islands as enclaves, but fishing grounds extend beyond them.

Table 1. Villages whose fishing grounds meet the indicative LSMPA boundary

Village (cluster)	Customary claim or sasi	Grounds vs boundary
Nolloth (Lease)	Sasi: lobster, trochus, sea cucumber	Inside (tuna)
Haria (Lease)	Not specified	Inside (tuna)
Pasir Putih (Buru)	Local FADs contested by outside fleets	Inside (tuna)
Tulehu (Ambon)	Sasi: bottom nets	Inside (tuna)
Ameth (Lease)	Communal traditional fishing	Partly inside
Asilulu (Ambon)	Not specified	Partly inside
Latuhalat (Ambon)	Hak ulayat over Lucipara Islands	Adjacent (enclave edge)

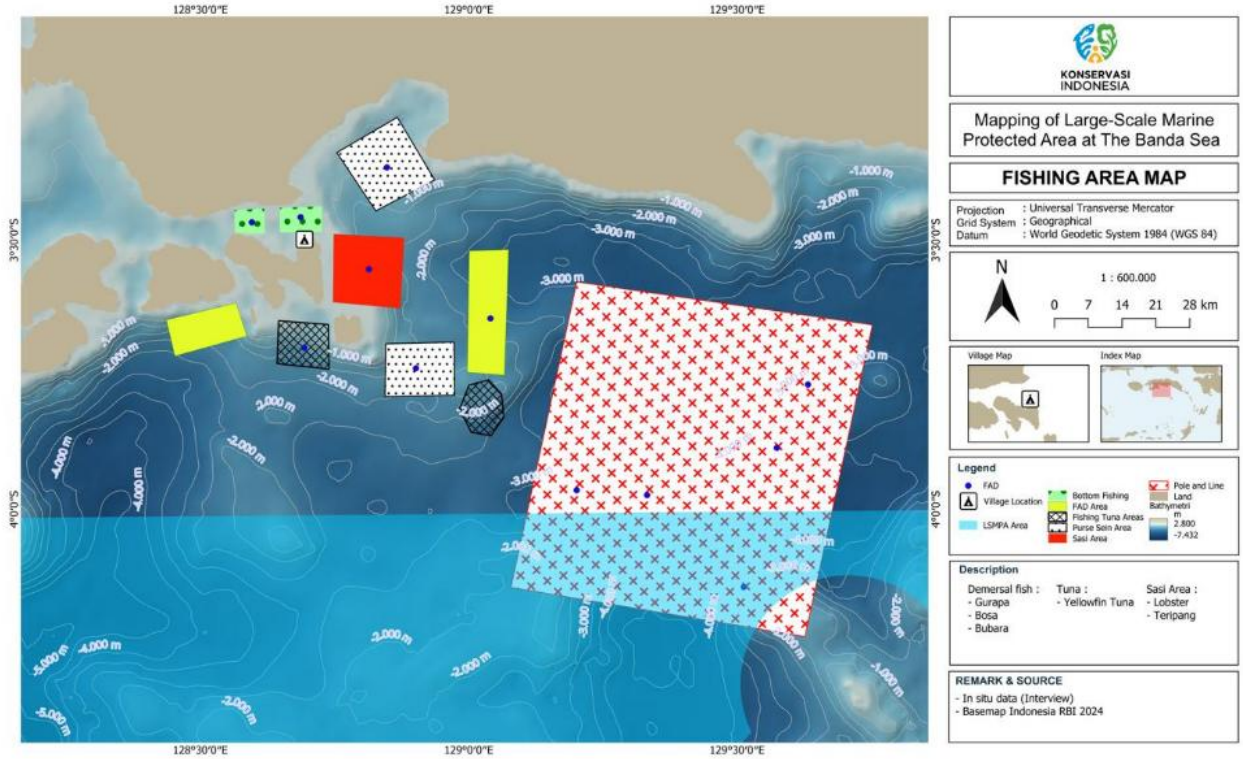


Figure 2. Digitised participatory map of Nolloth, Saparua: a customary sasi area for lobster and sea cucumber (red) near the village, and pole-and-line tuna grounds extending into the indicative LSMPA area (light blue). Source: Universitas Pattimura and Konservasi Indonesia (2026).

5. Discussion: where ecological value meets customary tenure

The ecological and social evidence point to the same places. Tuna is a priority conservation target and also the main catch: tuna was named by 224 surveyed fishers and skipjack by 206, and tuna grounds account for most of the mapped overlap. Fishers also observe the megafauna the LSMPA aims to protect, as 54.4% reported whales, dolphins, manta rays, dugongs, turtles or sharks near their villages. Local

legitimacy is therefore an ecological condition, because tuna outcomes depend on how fishers behave in and around the LSMPA. The shared perception of decline offers an entry point for co-management.

Because most of the LSMPA is open ocean, tenure matters most along the northern coastal edge and around the enclaved and offshore islands. This supports a tenure-first sequence for zoning:

1. Map petuanan, sasi areas and fishing grounds as primary layers, and quantify their overlap with the boundary.
2. Consult first with villages whose grounds fall inside or next to the boundary.
3. Recognise active sasi in zoning rules, and support its revival where it is eroding, as in Nolloth.
4. Place higher protection first on offshore priorities such as seamounts, deep basins and megafauna foraging areas, and zone coastal edges and enclave margins for sustainable traditional fisheries.
5. Negotiate rules and alternative livelihoods by island cluster rather than uniformly.

6. Conclusion

The Banda Sea merits basin-scale protection for its oceanographic processes, habitats and migratory species, but the same waters sustain island communities with customary claims. Because ecological value and customary use overlap, the LSMPA will succeed only if tenure and sasi are treated as primary zoning inputs. The next steps are to quantify spatial overlap, verify claims with customary leaders, add data from the ecological survey that began in October 2026, and carry the results into consultations before designation in 2027.

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Embedded Instrumentation for Sustainable Infrastructure Development in Archipelagic Regions: A Preliminary Rock Assessment Approach

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Sustainable development of infrastructure in island (archipelago) environments is predicated on having good information on the properties of the local rock. In many cases the remote islands will have very limited access to laboratory facilities and the specialist equipment required to perform the necessary testing. This paper describes a preliminary rock assessment technique using a compact embedded load monitoring system comprising a load cell, signal conditioning electronics and a microcontroller. The system is used to monitor the changes in load during a series of controlled mechanical loadings and can be used to provide some preliminary rock characterisation and an assessment of rock brittleness. The information it provides could be used to inform the choice of foundation material, to provide some preliminary insight into the behaviour of rock under seismic loading and to assist in geological surveys for mineral exploration. The system is designed to be portable and simple to operate and has potential application in island environments such as Maluku in Indonesia where the geographical isolation of the islands makes infrastructure development and geological investigation a significant challenge. It is a technique which could be used to supplement conventional geotechnical testing, and which would in principle help to build up local technical capability for the sustainable management of resources. It will of course require further validation against standard testing procedures to establish the accuracy, repeatability and reliability of the measurements.

Keywords: Embedded instrumentation, rock assessment, sustainable infrastructure, archipelagic regions.

Customary Institutions and the Governance of Mangrove Commons: Lessons from Maluku, Indonesia

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Abstract

Mangrove ecosystem services provide valuable benefits for humans and the environment, particularly for Indonesia's coastal communities. Although many studies have examined the general capacity of customary institutions, limited research has examined how long-established customary institutions rooted in customary communities govern mangrove ecosystems, especially in southeastern Maluku Province. This study used a qualitative case study approach and applied Ostrom's eight design principles as a theoretical framework to assess customary mangrove governance. As an initial case study, this study explores mangrove governance in Evu customary village, Southeast Maluku Regency, within the broader customary governance structure of Ratshap Yarbadang. The findings show that the customary institutional arrangement reflects Ostrom's eight design principles. They also demonstrate that interactions with formal government institutions support or complement customary governance. This case provides a foundation for a subsequent comparative investigation of customary mangrove governance in this regency and offers an opportunity to explore the interplay between customary institutions and state authorities in archipelagic mangrove governance.

Keywords: common-pool resource, Elinor Ostrom, mangrove conservation, Ohoi Evu, Ratshap Yarbadang.

Balancing Tradition and Ecology: Changes in Protected Marine Species and Associated Organism Groups Before and After *Sasi* in Maluku

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Abstract

Sasi system in Maluku has received considerable scholarly attention as a traditional, community-based approach to marine resource management. Much of the existing literature has focused on customary institutions, resource-use restrictions, community compliance, and the broader implications of traditional ecological knowledge for marine conservation. A key research gap lies in the limited integration of traditional marine resource governance with quantitative assessments of predator–prey dynamics. This study aims to evaluate the relationship between SASI tradition effectiveness and the balance of marine ecology through the dynamic of prey-predator in Rutong village waters. Using descriptive qualitative approach, we conducted deep interviews to fishers, public figures and village officials. The questions focus on the animals subject to *sasi* as preys and animals functioned as predators, the size and number of catch obtained before, during and after *sasi.* Principal component analysis and food chain stability index were used to understand the prey-predator correlation. For *sasi'* animals, population of topshells (*Rochia niloticus*) after *sasi* increased 129%, lobster (*Panulirus spp)* increased 141% , and seacucumber increased 90%. Based on local perspective, the catch of predator animals remained the same during the three phases of *sasi.* Some of non-economical animals such as sea urchins, sea stars, stingrays and puffer fishes were discarded lively. Sea cucumbers and their predators have a much closer prey-predator relationship than lobsters which preyed by octopus and trigger fish. Food chain stability indexes increased after *sasi.* These findings confirm that SASI is not merely a social system, but also an ecological mechanism rooted in local wisdom that contributes to the balance of marine populations in coastal areas.

Keywords: Lobster, Local knowledge, *sasi,* Seacucumber, Topshell

Ritual Communication Within The Cultural Space of The Maluku Islands Society in The Digital Era

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Abstract

In this research, ritual communication does not just function as a means of sharing beliefs, mutual commitment, and strengthening socio-cultural values. but how the Transmission View in ritual communication is understood as sending messages or information from one party to another with the aim of control, long distance distribution, or geographic influence on island communities in the digital era. Using a descriptive method of analysis with a qualitative approach, aimed at understanding the phenomenon of the object under study, so that it can be understood how the perception, description of behavior, motives and goals to be achieved by the object. This study aims to describe and/or reconstruct the discourse surrounding James W. Carey's ideas on "ritual communication"—understood as the transmission of messages or information from one party to another for the purposes of control, long-distance dissemination, or exerting influence—specifically within the context of the island communities of the Maluku region in the digital era. The findings are as follows: 1. The transmission view focuses on the control of a geographical territory, whereas the ritual view focuses on the maintenance of a community over time. 2. In the classical transmission view, the primary challenge for island communities is geographical barriers (the separating oceans). Conversely, the digital era has transformed the nature of "transmission"—now taking the form of video (such as YouTube or Facebook live streams) or digital documentation shared with community members who have migrated elsewhere. 3. The transmission view (the dissemination of information) and the ritual view (the maintenance of a society through time and shared experience) converge in the digital era. In conclusion, within the digital age, the transmission view in the communication of island communities is no longer solely concerned with how to send instructions or news across the ocean; rather, digital transmission has become a vital instrument for extending the reach of ritual communication.

Keywords: Ritual communication, island communities, Maluku, digital era

From Local Data to Island Value: AI for Sustainable Archipelagic Communities

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Abstract

Island communities require artificial intelligence applications that reflect local resources, operational conditions, and cultural priorities. This presentation examines how research in Maluku, Indonesia, can connect local data with decision support and future value for archipelagic communities. It synthesizes published studies, exploratory research, and an emerging digital heritage initiative through a framework linking problem definition, data preparation, model evaluation, human review, and outcome assessment. The cases include explainable seaweed quality assessment, tuna loin grading, fish image classification, human factors in fisheries, consumer sentiment analysis, and music documentation. A pruned decision tree study using 259 seaweed procurement records reported approximately 63.4% classification accuracy and informed a decision support prototype. Tuna research applied convolutional neural networks to Alpha and Bravo quality grading through a web application. In fish image classification, models trained on 365 online images were tested on 54 images from Mardika Market, Ambon. Random Forest achieved 83.33% accuracy, compared with 77.78% for Support Vector Machine, although the latter achieved higher recall for the Diseased class. Exploratory fisheries research integrates facial movement indicators and trip duration with catch per unit effort modeling. Additional applications examine packaging preferences and digital management of Maluku music heritage. Together, these cases demonstrate opportunities for locally grounded AI while distinguishing model performance from demonstrated sustainability outcomes. Priorities include representative datasets, independent validation, community participation, responsible governance, and evaluation of decision usefulness. The presentation proposes collaborative field validation to establish whether AI can improve decisions and generate measurable economic, social, cultural, and environmental benefits across diverse island settings.

Keywords: artificial intelligence; archipelagic sustainability; decision support; fisheries; Maluku

Integrating Local Resources through Green Tourism: A Resource-based Community Resilience Model for Offshore Island Revitalization

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Abstract

Offshore island communities face increasing challenges from population aging, youth outmigration, and economic decline, threatening their long-term sustainability. This study investigates how diverse local resources can be integrated through intergenerational co-creation and green tourism to enhance community resilience. Using Huxi Township in the Penghu Archipelago, Taiwan, as a qualitative case study based on long-term community engagement, the research examines three community initiatives involving cultural heritage, rural regeneration, and geotourism. The findings reveal a common revitalization pathway in which local resources are transformed into multidimensional community value through intergenerational co-creation and green tourism. Based on these findings, this study proposes a Resource-based Community Resilience Model (RCRM), providing a transferable framework for sustainable revitalization in offshore island and rural communities facing demographic and socioeconomic challenges.

Keywords: Offshore Island Communities; Community Resilience; Green Tourism; Intergenerational Co-creation; Regional Revitalization

1. Introduction

Offshore island communities worldwide are increasingly confronted with population aging, youth outmigration, and economic decline, which threaten local livelihoods, cultural continuity, and long-term sustainability. Compared with mainland regions, these communities are more vulnerable because of geographical isolation, limited economic opportunities, and dependence on local resources (Baldacchino, 2018). Recent studies have emphasized that sustainable development in rural and remote regions requires place-based strategies that integrate local resources, community participation, and social innovation (OECD, 2020; National Development Council, 2021). For many offshore islands, local resources—including cultural heritage, agricultural landscapes, and natural environments—represent not only development assets but also the foundation for long-term community resilience.

Green tourism has emerged as an effective approach for promoting sustainable regional development by combining environmental conservation, cultural heritage, and local economic development. Rather than focusing solely on tourism growth, green tourism encourages community participation and the sustainable use of local resources (Lane, 1994; UNWTO, 2020). At the same time, community resilience has become an important concept for understanding how local communities adapt to demographic and socioeconomic change through social capital, local knowledge, and collective action (Magis, 2010; Berkes & Ross, 2013). However, previous studies have primarily examined green tourism, community resilience, or regional revitalization as separate themes. Limited attention has been given to how intergenerational co-creation integrates diverse local resources through green tourism to strengthen resilience in offshore island communities.

Taiwan has promoted regional revitalization as a national strategy to address population decline, youth migration, and regional imbalance through local industry development and community participation (Executive Yuan, 2023; National Development Council, 2021). Against this policy background, the Penghu Archipelago provides a representative offshore island case characterized by rich cultural, agricultural, and geological resources alongside demographic challenges. Based on long-term community engagement and participatory observation, this study investigates how different local resources can be transformed into community resilience through intergenerational co-creation and

green tourism. It further proposes the Resource-based Community Resilience Model (RCRM) as a transferable framework for sustainable revitalization in offshore island communities.

2. Methodology

This study adopts a qualitative case study approach to examine how local resources contribute to community resilience through green tourism in Huxi Township, Penghu. Case study research is appropriate for investigating contemporary social phenomena within their real-life contexts, particularly when community development involves complex interactions among local resources, social participation, and tourism practices (Yin, 2018).

The study is grounded in long-term community engagement and adopts a practice-based research perspective. Data were collected through participatory observation, document analysis, and field records accumulated during community revitalization projects (Creswell & Poth, 2018; DeWalt & DeWalt, 2011). These complementary data sources enabled a contextual understanding of how local resources were mobilized and transformed through community-based practices.

Three representative communities—Nanliao (cultural heritage), Hudong (rural regeneration), and Beiliao (geotourism)—were purposively selected because they represent different types of community assets within Huxi Township. Rather than serving as comparative cases, they were used to illustrate common pathways through which diverse local resources can be integrated via intergenerational co-creation and green tourism to enhance community resilience. The cross-case synthesis further informed the development of the proposed Resource-based Community Resilience Model (RCRM).

3. Results

3.1 Cultural heritage and community participation

The Nanliao case demonstrates how cultural heritage can be transformed into a community asset through green tourism. Traditional *Caizhai* (stone-walled vegetable gardens), coral stone architecture, ancient wells, and farming practices have been preserved as living cultural landscapes and incorporated into experiential tourism activities. Rather than functioning solely as historical attractions, these cultural resources provide opportunities for local residents to reinterpret traditional ecological knowledge through visitor experiences and environmental education. Older residents contribute local history, agricultural knowledge, and cultural narratives, while younger generations support experience design, destination branding, and digital promotion. Through the integration of traditional knowledge and tourism innovation, cultural heritage is transformed from a historical asset into a dynamic resource for community development, strengthening cultural identity and creating community-based employment opportunities.

3.2 Agricultural revitalization through green tourism

The Hudong case illustrates how agricultural resources can support community resilience through rural regeneration and green tourism. Community initiatives have improved rural landscapes, promoted environmentally friendly farming, and developed agricultural experience programs that connect visitors with local lifestyles and seasonal farming activities. Older farmers contribute practical knowledge and farming experience, whereas younger generations introduce product innovation, tourism interpretation, and digital marketing. The integration of agriculture, community participation, and tourism has diversified local economic activities, strengthened local value chains, and enhanced residents' willingness to participate in community development, thereby contributing to rural revitalization.

3.3 Geotourism as a resource for sustainable development

The Beiliao case highlights the potential of geological heritage as a community asset for sustainable development. Its basalt landscapes, coastal scenery, and marine environment have become valuable resources for geotourism and environmental education. Community participation enables geological

heritage to be interpreted through place-based storytelling and guided experiences. Older residents contribute historical memories and local knowledge, while younger generations introduce innovative interpretation methods and digital communication tools. The interpretation of geological heritage not only expands sustainable tourism opportunities but also enhances visitors' environmental awareness while reinforcing residents' sense of place and environmental stewardship.

Table 1. Resource-based pathways of community revitalization in Huxi Township

Community Asset	**Representative Case**	**Intergenerational Co-creation**	**Community Outcome**
Cultural Asset	Nanliao	Traditional knowledge, tourism innovation	Cultural preservation and employment
Agricultural Asset	Hudong	Farming knowledge, experience design	Rural revitalization
Geological Asset	Beiliao	Local interpretation, digital communication	Sustainable geotourism

Although the three communities are characterized by different community assets, they reveal a common revitalization pathway. In each case, local resources are transformed into community assets through intergenerational co-creation and subsequently developed into green tourism experiences that generate social, cultural, environmental, and economic value. These findings suggest that community resilience depends less on the type of local resource than on the community's capacity to integrate local knowledge, community participation, and tourism innovation. This shared pathway provides the empirical foundation for the proposed Resource-based Community Resilience Model (RCRM).

4. Discussion

The findings indicate that the resilience of offshore island communities depends not on the abundance of tourism resources but on the community's capacity to integrate local assets through collective action and intergenerational collaboration. Although Nanliao, Hudong, and Beiliao utilize different forms of community assets—including cultural heritage, agricultural landscapes, and geological resources—they share a common revitalization pathway. In each case, older residents contribute local knowledge, cultural memory, and practical experience, while younger generations introduce innovation, tourism planning, and digital communication. Green tourism therefore functions not as an end in itself, but as a mechanism for transforming local resources into social, cultural, environmental, and economic value.

Based on these findings, this study proposes the Resource-based Community Resilience Model (RCRM) (Figure 1). The model suggests that sustainable revitalization begins with the identification and integration of local resources, followed by intergenerational co-creation that transforms local knowledge into innovative green tourism experiences. These processes strengthen community participation, create employment opportunities, preserve local identity, and enhance environmental stewardship, ultimately contributing to community resilience and sustainable offshore island development. Although developed from the experiences of Huxi Township, the proposed framework extends beyond a single case by providing a transferable approach for other offshore island and rural communities facing similar demographic and socioeconomic challenges.

The proposed model extends existing studies on green tourism and community resilience by emphasizing the role of local resource integration as the foundation for sustainable revitalization. Rather than treating tourism as the primary objective, the model positions green tourism as a mechanism through which communities transform local assets into shared value and long-term resilience.

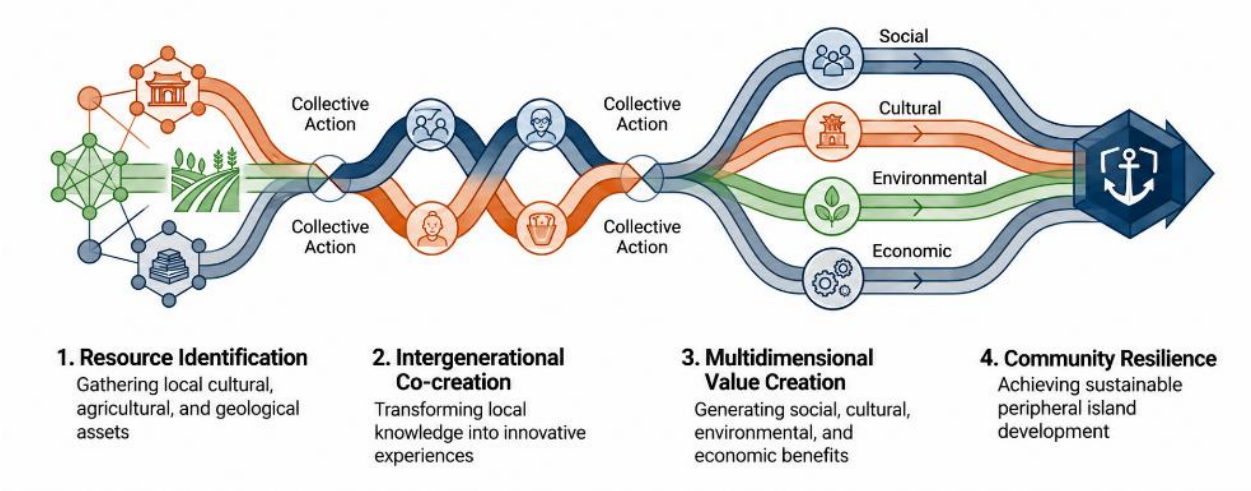


Figure 1 Conceptual framework of the proposed Resource-based Community Resilience Model (RCRM).

5. Conclusion

This study investigated how offshore island communities can enhance community resilience by integrating diverse local resources through intergenerational co-creation and green tourism. Using Huxi Township in the Penghu Archipelago as a practice-based case study, the findings demonstrate that cultural heritage, agricultural landscapes, and geological resources can be transformed into community assets when supported by collaboration between older residents and younger generations. Rather than relying solely on tourism development, sustainable revitalization is achieved through the integration of local resources, community participation, and shared value creation.

Based on these findings, this study proposes the Resource-based Community Resilience Model (RCRM), which illustrates a common revitalization pathway from local resource identification to intergenerational co-creation, multidimensional value creation, and ultimately community resilience. The model extends existing research by positioning green tourism as a mechanism for transforming local assets into social, cultural, environmental, and economic value, rather than as an end in itself.

Although developed from the experiences of Huxi Township, the proposed framework provides a transferable approach for other offshore island and rural communities facing demographic decline and economic transition. Future research may validate the proposed model through comparative studies across different island regions and explore how diverse community assets influence resilience-building under varying socioeconomic conditions.

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Sustaining small island aquaculture: Annual catch patterns and seedstock dynamics of juvenile trevally (*Caranx* spp.) in Ambon Bay

J.W. Mosse and B.G.Hutubessy

Abstract

Marine aquaculture in small island ecosystems relies heavily on the predictable availability of high-quality wild seedstock. In Ambon Bay, juvenile trevally species represent a crucial link between traditional capture fisheries and local floating net cage (*keramba jaring apung*) grow-out operations. Four sympatric species were identified in local catches: Giant Trevally (*Caranx ignobilis*), Bigeye Trevally (*Caranx sexfasciatus*), Bluefin Trevally (*Caranx melampygus*), and Blue-spotted Trevally (*Caranx verdau*), with *Caranx ignobilis* constituting the primary and most abundant species harvested for cage culture. This study presents a 12-month assessment of juvenile trevally catch dynamics, species composition, and harvesting practices in Ambon Bay. Monthly catch data were monitored across local fishing grounds where fishers exclusively utilize hook-and-line gear rather than nets. This technique is significantly safer for seedstock collection, avoiding net-induced descaling and skin abrasion. Fishers carefully unhook juveniles from the mouth to minimize tissue damage and post-capture mortality prior to cage stocking. The 12-month dataset revealed distinct seasonal recruitment peaks, with *C. ignobilis* showing clear temporal abundance patterns tied to environmental transitions. Length-frequency distributions confirmed that caught juveniles match optimal sizes for initial cage grow-out. Combining non-damaging gear with gentle unhooking practices significantly enhances seedstock survival rates. Integrating these species-specific catch patterns and safe handling practices provides actionable baseline data for coastal managers. Aligning stocking schedules with peak recruitment periods secures a reliable seed supply while preventing wild stock overexploitation, supporting sustainable Blue Economy development in small island communities.

Keywords: Small island, sustainability, trevally fish, wild-seeds, cage culture.

Geographical Barriers to Timely Stroke Care: A Case Report of Haemorrhagic Stroke Referred from Bula to Ambon, Maluku, Indonesia

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Background

Timely access to acute stroke care remains a major challenge in geographically dispersed archipelagic regions, where long distances and limited healthcare resources may delay definitive management. In the Maluku Islands, eastern Indonesia, inter-hospital referral often involves prolonged transportation, creating additional challenges in managing acute neurological emergencies. This case highlights the implications of geographical barriers for haemorrhagic stroke care in an archipelagic healthcare setting.

Case Presentation

A 44-year-old man was referred from Bula Regional General Hospital to Dr. M. Haulussy Regional General Hospital in Ambon, Maluku, Indonesia, presenting with sudden-onset right-sided limb weakness, speech impairment, and headache, which had developed approximately one day before admission. According to his family, the neurological deficits were first noticed upon awakening. Neurological examination revealed right-sided hemiparesis, with muscle strength graded 1/5 in the upper limb and 2/5 in the lower limb, accompanied by positive pathological reflexes on the right side. Non-contrast head computed tomography demonstrated a hyperdense lesion (59 HU) extending from the left corona radiata to the caudate nucleus, accompanied by extensive perifocal oedema, compression of the lateral ventricle, and subfalcine herniation measuring 0.51 cm. The inter-hospital referral journey from Bula to Ambon required approximately 11 hours of land transportation. During the referral process, the patient was reported to have become less responsive.

Discussion

This case illustrates the challenges of delivering timely stroke care in geographically isolated island communities. The prolonged inter-hospital transfer highlights the potential impact of geographical barriers on access to specialised neurological services and timely management of acute intracerebral haemorrhage. The presence of extensive perifocal oedema and subfalcine herniation further emphasises the importance of early recognition, neurological monitoring, and appropriate stabilisation before and during patient transfer. Telemedicine and teleneurology consultations, structured referral protocols, pre-notification systems, and improved inter-hospital coordination may help strengthen emergency stroke pathways in remote island settings.

Conclusion

Acute haemorrhagic stroke management in archipelagic regions requires more than adequate clinical facilities; it also depends on an effective and geographically responsive referral system. Strengthening telemedicine, pre-transfer stabilisation, and emergency transportation coordination may improve access to timely stroke care and support more equitable neurological healthcare services across Maluku, Indonesia, and other geographically dispersed communities.

Pre-Feasibility Study on The Impact Of Renewable Energy on Poverty Alleviation Among Fisher and Farmer Households in Maluku

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Background & Socio-Economic Context

In the archipelagic Province of Maluku, rural coastal communities face a severe socio-economic disparity, remaining nearly five times poorer than urban populations. This persistent inequality is rooted in premature national deindustrialization since the early 2000s, during which the manufacturing sector's share of GDP has plunged from 23% in the late 1980s to a mere 6.5% today. Driven by severe fiscal constraints, crumbling transport infrastructure, exorbitant transaction costs, and weak market connectivity, rural coastal households have become trapped in two reinforcing structural barriers: a *Vicious Cycle of Poverty* (low capital → traditional gear → rapid spoilage → low income) and a *Geographical Poverty Trap* (extreme isolation, retail fuel prices of IDR 15,000–19,000/liter, and non-existent cold chains). Decentralized renewable energy—specifically, Productive Use of Energy (PUE)—offers a transformative catalyst for breaking these poverty traps through localized value addition, rural industrialization, and energy autonomy across 10 priority pilot villages in Maluku.

Research Problem & Research Questions

Small-scale fishers in Maluku operating 15–30 HP outboard boats (*perahu)* must travel 20–40 nautical miles to oceanic waters or to FADs (rumpon), spending 18–24 hours at sea. The lack of reliable, affordable ice forces fishers to use either commercial block ice or domestic plastic ice bags, which melt within 6-7 hours. The resulting thermal abuse accelerates the conversion of histidine to histamine, degrading high-value yellowfin tuna from Grade A/Sashimi (IDR 55,000–75,000/kg) to Grade C or local cooking fish (IDR 20,000–28,000/kg)—inflicting a 30%-50% loss of income. Simultaneously, smallholder spice farmers face severe post-harvest decay: traditional open-sun drying during monsoon periods retains excessive moisture (>15%) and encourages contamination by the toxic *Aspergillus flavus* mold (*aflatoxin*), resulting in farmgate price penalties of 30% to 40%.

To address these critical bottlenecks, this study poses four central research questions: (RQ1) What are the financial pre-feasibility metrics (Capex, Opex, PBRA Net, BCR, PBP, BEP) for deploying standalone and integrated PUE technologies across coastal villages? (RQ2) How much post-harvest economic value leakage can be recovered in yellowfin tuna and spice value chains through solar cooling and UV drying? (RQ3) How resilient are PUE investments against operational shocks, price slumps, and demand fluctuations under formal sensitivity and switching-value stress testing? (RQ4) What holistic institutional governance model (BUMDes/Cooperative) can sustain long-term PUE operations, technical maintenance, and equitable profit distribution?

Research Objectives

The study pursues four explicit objectives: (1) Evaluate the financial pre-feasibility of 6 standalone and integrated PUE options using PBRA metrics; (2) Quantify post-harvest value chain quality recovery (VCA) for yellowfin tuna and cash crops; (3) Perform rigorous sensitivity and switching-value stress tests against demand, price, and Capex shocks; and (4) Formulate an institutional BUMDes/Cooperative co-management business model with private export off-takers.

Research Methodology

A 5-stage Multi-Criteria Decision Analysis (MCDA) framework was deployed to evaluate 500 coastal villages across Maluku, narrowing down to 40 candidate sites and ultimately selecting 10 priority pilot villages. Field research combined micro-surveys across fisher and farmer households (R1–R9

instruments), Focus Group Discussions (FGDs), key informant interviews with traders (jibu-jibu/papalele), and participatory GIS mapping of fishing grounds, FAD locations, and solar irradiation zones.

Results and Discussion

Standalone PUE Technology Pre-Feasibility (PBRA Evaluation)

All six standalone and integrated PUE technology options demonstrate exceptional financial viability under baseline operational parameters. Table 1 summarizes the capital costs (Capex), annual operating expenses (Opex), PBRA quadrant shifts, net annual revenue, Benefit-Cost Ratios (BCR), and Payback Periods (PBP).

Table 1. Standalone Pre-Feasibility Metrics Across 6 PUE Technology Options.

PUE Technology Option	Capex (IDR)	Opex (IDR/Yr)	K1: Added Rev.	K2: Red. Cost	PBRA Net (IDR/Yr)	BCR	PBP (Yrs)
1. Solar Ice Plant (3–5t)	730,000,000	105,000,000	480,000,000	240,000,000	375,000,000	2.08	1.95
2. Solar Cold Storage (3t)	370,000,000	45,000,000	225,000,000	45,000,000	225,000,000	2.15	2.06
3. Solar Drying Dome (2–5t)	220,000,000	65,182,000	407,682,000	65,200,000	407,700,000	2.66	0.76
4. Solar PV+BESS (75 kWp)	1,250,000,000	180,000,000	180,000,000	420,000,000	420,000,000	1.85	3.25
5. Solar Rumpon (LED FAD)	30,000,000	6,600,000	52,800,000	6,600,000	52,800,000	3.10	0.71
6. Jibu-Jibu Coolbox Unit	12,500,000	3,200,000	45,600,000	3,200,000	45,600,000	2.45	0.15

Household Income Transformation

Deployment of tailored PUE technology packages across the 10 priority villages unlocks immense economic value. By transforming renewable energy, i.e., solar energy, to replace fossil fuels, and transforming local ice into ice packs, fishers' income will increase more than twice. As a result, fisher households will transition from poor to non-poor. At the same time, income from spices and coconuts will double farmers' income. Table 2 details the village-level investment parameters and the transformation of net monthly income. Rural coastal households who work both in fisheries and agriculture will improve their income optimally by increasing the quality of the product to increase the selling price and, at the same time, to reduce fuel and ice costs. Parigi village for example increase from 3.5 million to 8.2 million per month.

Table 2. Integrated 10 Priority Village Investment Master Matrix and Household Income Leaps.

Priority Village	Code	Capex (IDR)	Opex (IDR/Yr)	K1: Added Rev.	K2: Red. Cost	Net Income (IDR/Mo)	BCR	PBP (Yrs)
1. Parigi	1,2,3,4	2,150,000,000	165,000,000	480,000,000	360,000,000	3.5M → 8.2M	2.12	2.05
2. Eli Besar	1,2,4	2,300,000,000	175,000,000	520,000,000	420,000,000	2.5M → 7.8M	2.24	1.98
3. Haya-Misa	1,2,3,4	2,050,000,000	155,000,000	450,000,000	380,000,000	3.0M → 7.5M	2.18	2.10
4. Pasir Putih	1,2,3,4	2,200,000,000	170,000,000	490,000,000	390,000,000	4.0M → 9.5M	2.15	2.02
5. Wailihang	1,2,3,4	2,400,000,000	180,000,000	580,000,000	440,000,000	4.5M → 11.2M	2.35	1.85
6. Talaga Nipa	1,2,3,4	1,950,000,000	145,000,000	420,000,000	340,000,000	2.0M → 6.8M	2.05	2.25
7. Latuhalat	1,2,4	1,850,000,000	140,000,000	410,000,000	350,000,000	3.0M → 7.9M	2.08	2.15
8. Nolloth	1,2,3,4	1,900,000,000	140,000,000	400,000,000	330,000,000	2.2M → 6.9M	2.02	2.28
9. Tulehu	1,2,4	2,100,000,000	160,000,000	470,000,000	370,000,000	3.5M → 8.8M	2.14	2.08
10. Kampung Baru	1,2,4	2,250,000,000	170,000,000	500,000,000	410,000,000	4.0M → 9.8M	2.20	1.92

Note: 1 = Solar Ice Plant (3–5 t), 2 = Solar Cold Storage (3 t), 3 = Solar Drying Dome (2–5 t), and 4 = Solar PV+BESS Microgrid (75 kWp).

Sensitivity Analysis & Operational Stress Testing

Formal sensitivity analysis and switching-value stress testing were executed to model investment resilience against extreme operational shocks: Scenario A (40% drop in ice/cold storage utilization or drying volume), Scenario B (25% drop in product price premium or +20% Capex overrun), and Switching Value Analysis (maximum tolerable shock buffer before BCR falls to the critical threshold of 1.0).

Key sensitivity findings demonstrate robust investment security across all technology options: (1) Solar Ice Plant: Under a 40% severe drop in ice demand (utilization falling to 60% or 1.2t/day), the Benefit-Cost Ratio remains comfortably viable at BCR= 1.29 (PBP 3.99 yrs). The critical switching value (BCR = 1.0) is reached only if ice utilization collapses below 46.6% (<932 kg/day) or if local ice prices drop below IDR 373/kg. (2) Solar Cold Storage: Operates with a 54.8% safety buffer against occupancy drops before hitting BCR = 1.0. (3) Solar Drying Dome: Possesses the highest resilience buffer (84.2% tolerable drop in price premium), maintaining a strong BCR = 1.57 even under a 50% slump in spice market premiums. (4) Solar PV+BESS Microgrid: Retains a 46.0% buffer against diesel price drops, confirming long-term fuel hedging efficiency.

Value Chain Quality Recovery (VCA)

Value Chain Analysis (VCA) establishes that solar ice production and dockside cold storage prevent thermal degradation, eliminating histamine buildup and locking in Grade A/Sashimi quality. This recovers IDR 25,000–50,000/kg in value leakage directly at the dock. For spice crops, solar drying domes eliminate moisture retention and *aflatoxin* mold, securing export price premiums of +20% to +35% for nutmeg, cloves, and edible white copra.

Holistic BUMDes/Cooperative Business Model & Governance

Long-term institutional sustainability is anchored in a co-governance structure connecting BUMDes/Village Cooperatives with private export off-takers (e.g., MDPI). Operational revenues are governed by a mandatory 5-Tier Profit Sharing Waterfall: 20% to a Sinking Fund (quarantined in a dedicated bank account for LiFePO4 battery replacement at Year 8), 35% to BUMDes Cash / Village Original Revenue (PADes), 20% to Working Capital Retained Earnings, 15% to the Fisher & Farmer Welfare Fund, and 10% to Performance Bonuses for trained local operators. Institutional trust is enforced through biannual public dockside audits and a transparent digital ledger.

Conclusion and Policy Implications

Decentralized renewable energy (PUE) investments across the 10 pilot coastal villages in Maluku represent a highly lucrative, low-risk strategy to break structural poverty traps, double household incomes, and catalyze rural industrialization. Three actionable policy recommendations are formulated: (1) Advance to Bankable Feasibility Study (FS): Transition immediately from pre-feasibility to a full Bankable FS supported by precise engineering designs for GEAPP, provincial government funding, and commercial impact investors; (2) Institutionalize Tripartite Off-take Contracts: Enforce formal tri-party co-management agreements between BUMDes, local fishers/farmers, and private exporters (MDPI) to guarantee market access and Grade A pricing; and (3) Local SDM Technical Capacity Building: Implement intensive technical training for 2 local operators per village to oversee daily PUE system operations, preventative maintenance, and battery bank health.

Acknowledgements

The authors express their sincere gratitude to Konservasi Indonesia (KI), the Global Energy Alliance for People and Planet (GEAPP), and the Institute for Research and Community Services (Lembaga Penelitian dan Pengabdian kepada Masyarakat - LPPM) of Pattimura University for their financial support, institutional backing, and operational guidance throughout this comprehensive multi-village study across Maluku Province.

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Chemical Characterization and Therapeutic Potential of Essential Oils from the Moluccas Islands

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Abstract

The Maluku Islands, historically known as the "Spice Islands," possess a rich biodiversity of aromatic plants yielding high-quality essential oils, notably clove (*Eugenia caryophyllata*) and nutmeg (*Myristica fragrans*). This study aims to characterize the chemical profiles and evaluate the therapeutic potential of essential oils indigenous to Maluku. Chemical characterization was conducted using Gas Chromatography-Mass Spectrometry (GC-MS) analysis. The results revealed a high concentration of dominant bioactive compounds, including eugenol in clove oil, alongside myristicin in nutmeg oil. These constituents exhibit significant biological activities, specifically potent antioxidant, and antibacterial. Such therapeutic potential highlights the viability of Maluku's essential oils as natural raw materials for the pharmaceutical, cosmetic, and aromatherapy industries. In summary, the diverse chemical constituents and promising medicinal properties of essential oils from the Maluku Islands justify their development as modern bio-therapeutic agents.

Keywords: Essential oils, Maluku Islands, GC-MS, myristicin, therapeutic potential

Introduction

Maluku is a well-known producer of essential oils from commodities such as cloves, nutmeg, and cajuput. Extracted from various plant species, these oils are rich in diverse chemical compounds, with oxygenated terpenes demonstrating potent therapeutic effects [1-2].This region, historically renowned as the "Spice Islands," possess a unique geographical and climatic profile that fosters an exceptionally rich biodiversity of aromatic plants. For centuries, this region has been the global epicenter for the cultivation of traditional spices, most notably clove (*Eugenia caryophyllata*) and nutmeg (*Myristica fragrans*) [3]. Beyond these well documented commodities, the archipelago is home to several endemic and underutilized aromatic species, such as *Melaluca cajuputi*, *Cananga odorata*, and local Cymbopogon species [4]. Modern pharmaceutical and phytochemical validation of this plant remains fragmentary, despite its high commercial and historical value. This group of aromatic plants utilizes volatile secondary metabolites as a natural defense system to ward off tropical pathogens and cope with environmental stressors. Environmental conditions in the Wallacea region such as soil characteristics, humidity, and weather drive the development of unique chemotype variations [5-6]. This study aims to analyze the chemical characterization and therapeutic potential (antioxidant and antibacterial) of six essential oils from significant plants native the Maluku Islands: *E. caryophillata*, *M. fragrans*, *C. cullilawan*, *M. cajuputi*.

Material and Method

Plant Material

Plant material (leaves, buds, and seeds) was collected from various habitats across three different islands in the Maluku archipelago: Ambon, Buru, and Seram. Samples were gathered during the dry season to maximize the yield of essential oils.

Isolation of EOs and Chemical Composition Analysis

In order to find the EOs, fresh plant material (6 kg) from sample was stem-distilled using conventional steam distiller as long as 6 hours. The product of EOs were then dried by s sodium sulphate anhydrous (Na_2SO4) and cool-stored in brown bottle for further analysis. Analysis of the structure and composition of ClO using GC and GC-MS from Shimadzu (QP-2010).

Bioactivty Evaluation of EOs

The DPPH and ABTS assay were performed according to the method for antioxidant activites described by Kainama et al., 2020 [7]. Ascorbic acid and BHT was used positive controls. Antibacterial Assay followed Lai et al., 2010 [8]. Four strains of bacteria use to assess the antibacterial properties is two Gram positive (*Bacillus subtilis FNCC0060* and *Staphylococcus aureus ATCC6538*) and two Gram negative bacteria (*Escherichia coli* FNCC0091 and *Salmonella typhimurium* FNCC0157).

All bacteria were grown on nutrient agar (Oxoid). Diameter of zone of inhibition was determined using the disc diffusion method as previously described (Mith et al. 2014) [8]. Determination of minimum inhibitory and bactericidal concentrations EOs which exhibited the best antimicrobial activity in the paper disk diffusion assay, and some individual constituents, were selected for determining the minimum inhibitory concentration (MIC) and the minimum bactericidal concentration (MBC) using broth dilution method

Results and Discussion

Chemical composition clove oil from Ambon Island and antibacterial activity

Five components were identified in the clove oil from West Ambon derived from buds, leaves, and stems. The primary components in the bud oil are eugenol (75.30%), eugenyl acetate (20.93%), and β-caryophyllene (3.00%), whereas the leaf oil contains eugenol (82.97%) and β-caryophyllene (12.84%), and the stem oil consists predominantly of eugenol (97.75%) (Fig. 1-Fig.2) The antimicrobial activity of these oils was tested in vitro against Gram-positive bacteria (*Staphylococcus aureus* and *Bacillus subtilis*) and Gram-negative bacteria (*Escherichia coli* and *Salmonella typhimurium*). The essential oils from the buds, leaves, and stems all demonstrated antibacterial activity against both bacterial groups.

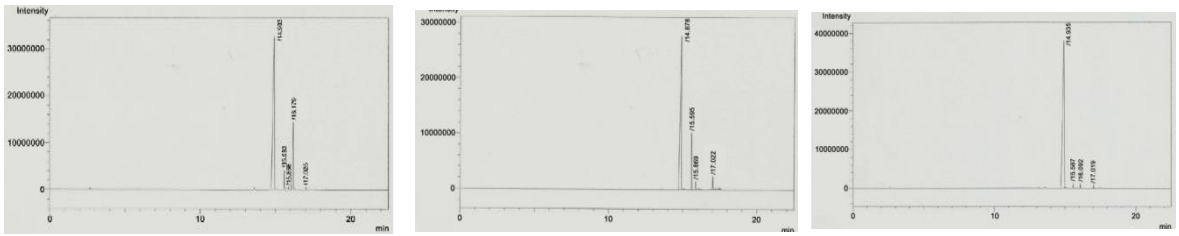


Figure 1. Chromatogram of clove oil from Ambon Island (A) Bud, (B) Leaf and (C) Stems

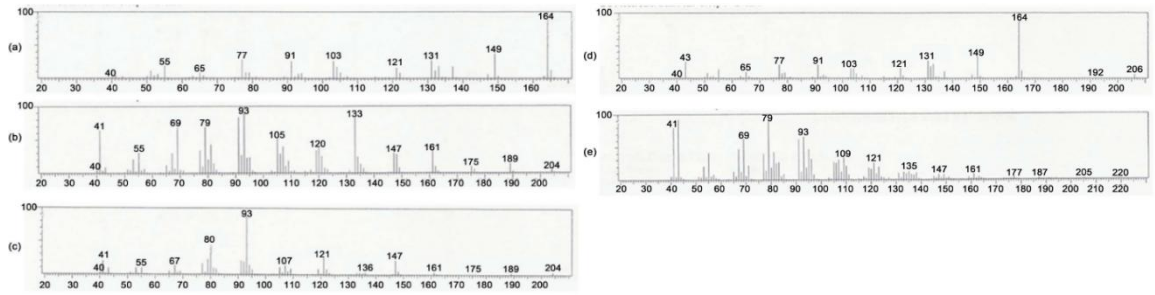


Figure 2. MS-Spectrum of ClO from Ambon Island (a) Eugenol, (b) β-caryophyllene, (c) Humulene Stems (d) Eugenyl acetate and (e) Caryophyllene Oxide.

Chemical composition clove oil from Buru Island and antioxidant activity

In total, five components were identified in ClO of leaf, four components were identified in ClO of bud, and two components were identified in ClO of stem. The main constituents are eugenol (77.1% to 78.8%) and β-caryophyllene (17.0% to 19.6%) in ClO of leaf. The main components are eugenol (76.1% to 87.7%) and eugenyl acetate (6.0% to18.9%) in ClO of bud and the only main component was eugenol (94.2% to 97.6%) in ClO of stem from Waihani (ClOWh), Ilath (ClOI) and Waimoli (ClOWy) (Fig.3-5) The antioxidant activity ClO of leaf, bud, and stem was identified using DPPH and ABTS assay. Results

showed that ClOI of bud had higher ABTS free radical scavenging (IC_{50} value: 0.09 ± 0.61 µg/mL) than the eight samples in the study. When this activity was compared with synthesis antioxidant of BHT (IC_{50} value: 0.83 ± 0.54 µg/mL) and AA (IC_{50} value: 0.81 ± 1.64 µg/mL), the ClO in three locations show potential of being used as an antioxidant.

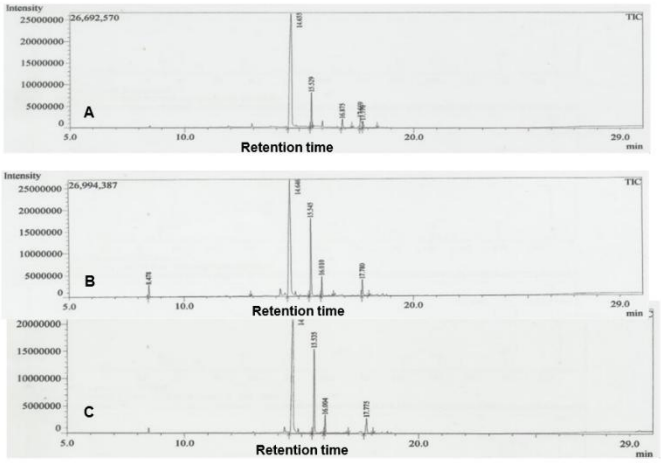


Figure 3. Chromatogram GC-FID of clove oil from Buru Island (A) ClOWh, (B) ClOI, (C) COsWy of leaf

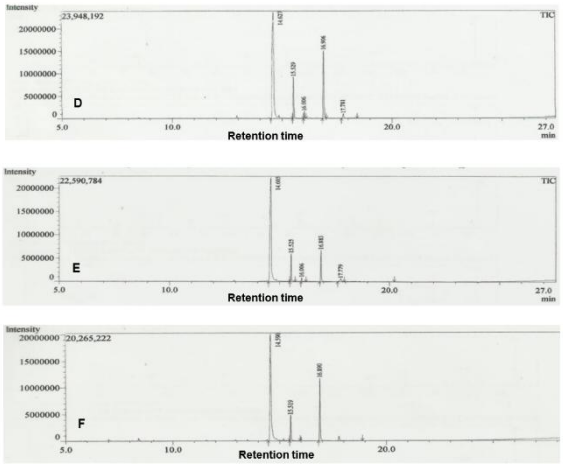


Figure 4. Chromatogram GC-FID of clove oil from Buru Island (A) ClOWh, (B) ClOI, (C) ClOWy of bud

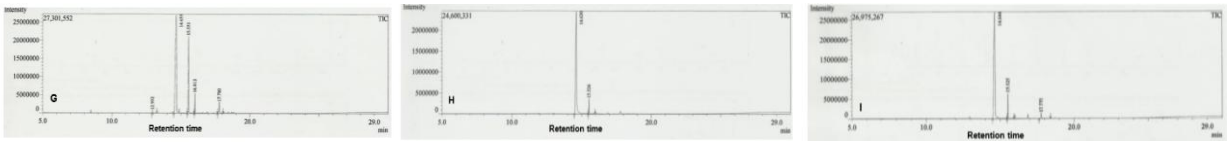


Figure 5. Chromatogram GC-FID of clove oil from Buru Island (A) ClOWh, (B) ClOI, (C) ClOWy of stem

Antioxidant ClO from Allane and Derivat Eugenol

The ClO from Allane showed that free radical activity of essential oil, main constituent and its derivatives were analized using in vitro method. ClO activity from stem obtained as (0.82±0.15 µg/mL) was higher than that from bud and leaf possessing both DPPH and ABTS radical scavenging assays by sinergism of eugenol, eugenyl acetate, β-caryophylene and humulene. The activity of isoeugenol (**2**) (3.59±0.54 µM) and (5.0±0.53 µM) scavenging DPPH and ABTS, respectively, as derivatives eugenol was higher than (**3**), (**4**) and (**5**). Although (**6**) was active originally, it was inactive after conversion of the ester. While the change of the double bond of location to conjungation structure caused more activity scavenging radicals than the starting molecule (Fig.6 and Fig.7)

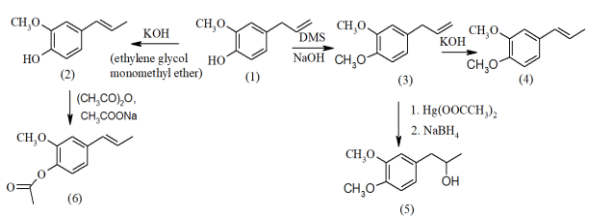


Figure 6. Derivatization scheme of

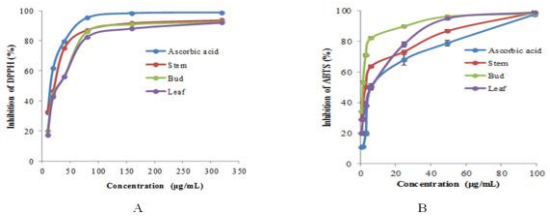


Figure 7. Scavenging effect of different EOs and AA (positive control) (A) DPPH, and (B) ABTS

Chemical Composition Antioxidant NO from Ambon dan Sawai

The essential oil of seed and mace nutmeg (*Myristica fragrans*, Houtt) from Ambon show that eight components were identified in seed oil and 10 component were identified in seed oil, The main component in seed oil are linalool (10.696 ± 0.187%), α-terpineol (13.384 ± 0.808%) and Myristicin (61.197 ± 0.613%)and the main component in mace oil are α-Pinene (13.975 ± 0.159%), sabinene (26.407± 0.456%), β-myrene (14.193± 0.429%), safrole (6.493± 0.326%) and myristicin (27.279 ± 0.735%) (Fig. 8 and Fig.9). In addition, this effect may be specific due to the chemical components of the

oil. The seed oils displayed high DPPH free radical scavenging activity with IC_{50} value of 2.48±0.42 µg/mL and 2.80±0.24 µg /ml respectively, and the ABTS free radical-scavenging activity with IC_{50} value of 1.09±0.25 µg/mL and 2.92±0.59 µg /ml, when compared with that of synthetic antioxidants BHT (1.03±0.10µg/mL) and (1.52±0.11µg/mL) (Fig. 10).

NO in mace from Sawai (Seram Island) indicate 21 components which is monoterpene hydrocarbon (53.13%), monoterpene oxygenated (14.9%) and phenyl propene (28.18%). Two main constituents were identified as β-Phellandrene (14.06%) and myristicin (14.60%). The proposed biosynthesis pathway regarding presence of compounds indicates that NO chemotypes are phellandrene and terpinene. NO in seed contains 21 compounds, with benzyl benzoate (12.66%) and myristicin (11.94%) as the two main components. The biosynthetic pathway indicates that NOsB possesses phellandrene and linalool chemotypes.

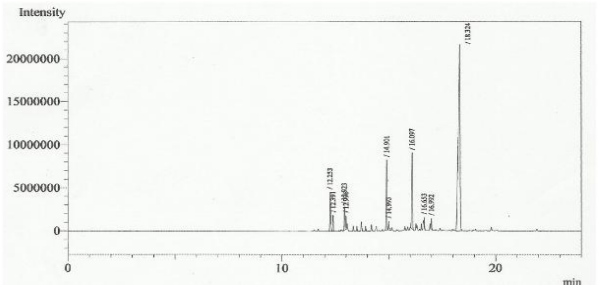


Figure 8. Chromatogram GC of seed from

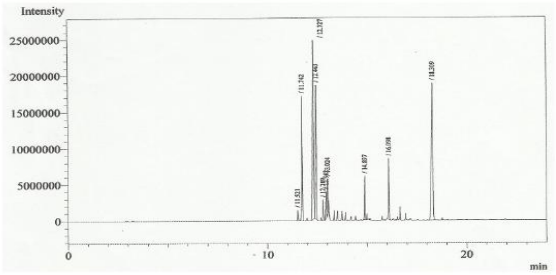


Figure 9. Chromatogram GC of mace from

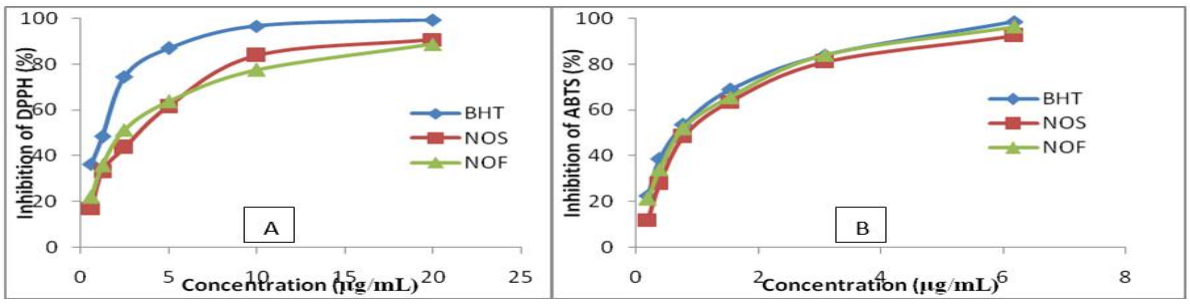


Figure 10. Antioxidant of NO from Ambon (A) DPPH, B (ABTS)

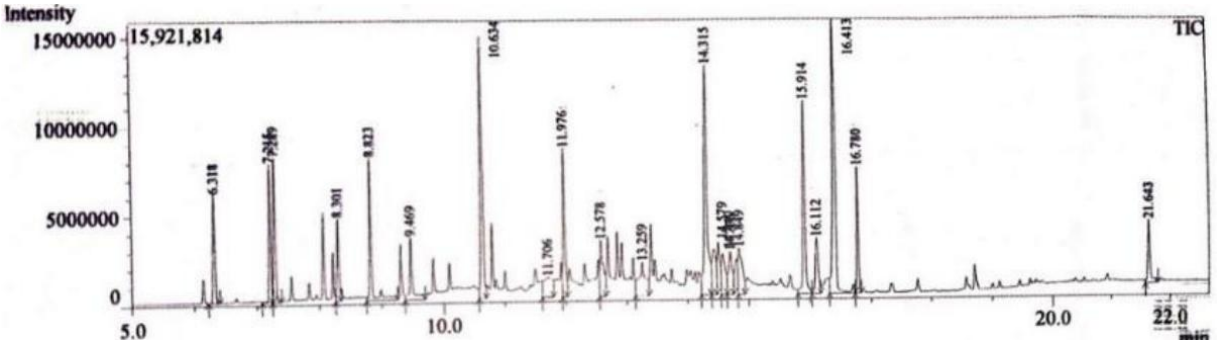


Figure 11. Chromatogram GC-MS of NOS from Sawai

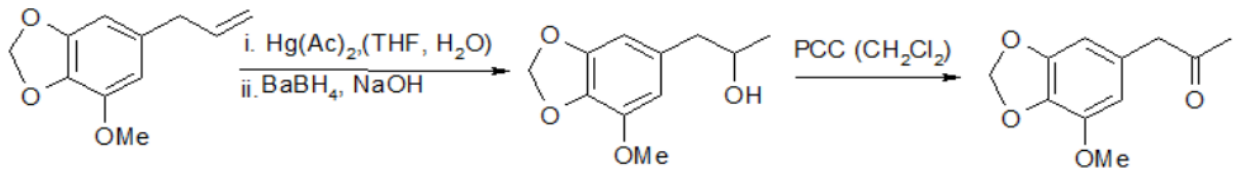


Figure 12. Scheme of synthesis of myristicin ketone -2-propanone

The synthesis of myristicin ketone from myristicin has been achieved through conversion of allyl group to ketone Fig.12). Myristicin was isolated from nutmeg oil. The reaction of myristicin with mercury acetate in aqueous tetrahydrofuran, followed by in situ reduction of the mercurial intermediate by alkaline solution sodium borohydride produced myristicin alcohol. Myristicin alcohol was oxidized with PCC at 40 0C for 90 minutes, followed by purified with saturated potassium disulphite yield myristicin ketone (3-methoxy-4,5-methylenedioxyphenyl)-2-propanone (68.32%).

Chemical composition in Cajuputi oil (COs)

Essential oils (EOs) from Melaleuca cajuputi leaves have chemotypes and local distribution influences its chemical composition. This paper reports chemical constituents of cajuputi oils obtained from Lektama village, South Buru District. These COs contained a significant amount of oxygenated monoterpenoids (72.3%), monoterpene hydrocarbons (17.81%), and sesquiterpene hydrocarbons (9.89%) (Fig.13). Oxygenated monoterpenoid was the most abundant component in the sample. We found the a-terpinyl as a precursor of cyclic monoterpenes in cajuputi oils from Lektama.

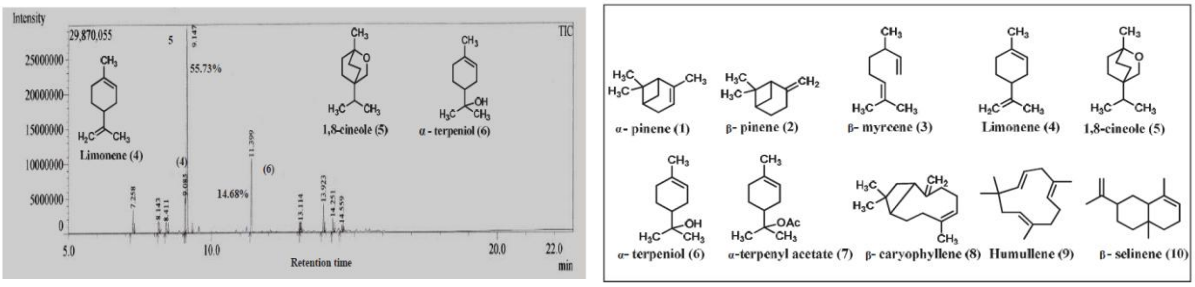


Figure 13. (A) Chromatogram GC-MS, (B) Structure of compounds in COs from Lektama

The chemical composition of essential oil from Cinnamomun culilawan, Bl, was obtained from steam distillation method, and its chemical composition was determined by GC and GC-MS. The result indicated that the essential oil is mainly phenylpropanoid compound (86.473%), the minor compounds are oxygenated monoterpenes (7.934%) and monoterpenes hydrocarbon (5.592%). The purification of the two main compounds yielded eugenol (51.66%), and safrole (6.71%).

Chemical composition in Cinnamomun cullilawan (CuOs)

The chemical composition of essential oil from Cinnamomun culilawan, Bl, from Allane show that phenylpropanoid compound (86.473%). The minor compounds are oxygenated monoterpenes (7.934%) and monoterpenes hydrocarbon (5.592%). The addition of a strong base to CuOs, followed by purification via fractional distillation, yields eugenol (**1**) (51.66%) and safrole (**2**) (6.71%). Spectrum IR (**1**) (cm-1): 3475, 2976, 2842, 1638, 1613, 1432, 1149, 1034. Spectrum ^{1}HNMR (400 MHz, $CDCl_3$, ppm), ∂: 3.41 (d $-CH_2$-, J = 6.8 Hz), 3.86 (s $-OCH_3$), 5.16 (d, $=CH_2$), 5.20 (s, -OH), 6.05 (m, -CH=, J = 6.8Hz), 6.76 (s, H, C3Ar), 6.78 (d, H, C6Ar), 6.98 (d, H5-Ar). ^{13}C-NMR (100 MHz, $CDCl_3$) ∂: 40.01 (-CH_2-), 55.95 (-OCH_3), 111.20 ($=CH_2$), 114, 37 (C2-Ar), 115.65 (C5- Ar), 121.26 (C6-Ar), 132.03 (C1-Ar), 137.95 (-CH=), 143.95 (C4-Ar), 146.53 (C3-Ar). Spectrum IR (**2**) (cm^{-1}): 2977, 2842, 1639, 1608, 1432, 1246, 1034. Spectrum ^{1}HNMR (400 MHz, $CDCl_3$, ppm), ∂: 3.33 (d $-CH_2$-, J = 6.4Hz), 5.10 (m, =CH2), 5.95 (s, -OCH_2O-), 6.00 (m, -CH=, J =6.4 Hz), 6.67 (d, H-C5Ar), 6.74 (s, C3-Ar), 6.84 (d, H-C6-Ar. ^{13}CNMR (100 MHz, $CDCl_3$): ∂: 40.06 (-CH_2-), 100.95 (- OCH_2O-), 108.30 (C3-Ar), 109.23 (C5-Ar), 115.82 ($=CH_2$), 121.44 (C6-Ar), 133.96 (C1-Ar), 137.80 (-CH=), 145.99 (C4-Ar), 147.90 (C3-Ar)

Conclusion

1. Essential oils extracted from aromatic plants native to the Maluku Islands possess chemical profiles dominated by monoterpenes and phenylpropanoids most notably 1,8-cineole, eugenol, α-pinene, and myristicin. Geographical factors, the altitude at which the plants grow, and the varying climates across the different islands of Maluku influence the quantitative composition of these chemical constituents.

2. From a pharmacological perspective, essential oils from the Maluku region hold promising therapeutic potential as antimicrobial, antioxidant, and anti-inflammatory agents, as well as natural pain relievers. Nevertheless, their widespread use in pharmaceutical and cosmetic preparations requires quality standardization, the regulation of safe limits for specific compounds (such as the safrole content in nutmeg oil), and further toxicity testing.

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Geographical distribution of Black Flies in The Amami Islands, Japan

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Abstract

Black flies (Simuliidae) are hematophagous insects of medical and veterinary importance, as females feed on the blood of mammals, birds, and humans. A survey of their geographical distribution across the Amami Islands, Japan, confirmed six species, with notable variation in composition among the islands. One island showed the highest biodiversity, hosting all six species. One species was the most widely distributed, occurring on nearly all surveyed islands with only a single exception. By contrast, two species were restricted to just two islands, while the remaining three exhibited intermediate distributions. These findings provide essential baseline data for understanding the ecological dynamics of black flies in the Amami Islands and offer valuable insight into their ecological role within the region's natural environment.

Keywords: black flies, Simuliidae, Amami Islands, island biogeography, stream ecology

Black flies (family Simuliidae) are insects of considerable medical, veterinary, and ecological significance. The females of most species are hematophagous, requiring a blood meal from mammals and birds—including humans and domestic livestock—to complete egg development. Through this blood-feeding behavior, black flies can cause painful bites, provoke allergic reactions, and, in many parts of the world, serve as vectors for pathogens and parasites of concern to human and animal health. Their immature stages are strictly aquatic and depend on clean, flowing water, making the group closely tied to the condition of river and stream environments. For these reasons, understanding the species composition and geographical distribution of black flies within a given region provides insight not only into public and veterinary health risks but also into the ecological integrity of local freshwater systems.

The Amami Islands of Japan represent a biogeographically distinctive setting for such an investigation. Situated within the northern Ryukyu Archipelago near the Watase Line— a major faunal divide separating the Palearctic and Oriental regions—these islands feature exceptional endemism and a remarkably diverse island ecological community. The fragmentation of the landscape into numerous islands of varying sizes, topographies, and hydrological characteristics creates a natural laboratory for examining how organisms are distributed across an archipelago. Given these unique conditions, an investigation into the geographical distribution of black flies across the Amami Islands confirmed the presence of six distinct species. The collected data reveal significant variations in species composition among the islands, reflecting differences in habitat availability, stream conditions, and the biogeographic history of each island.

Amami-Oshima Is., the largest and topographically most diverse island in the group, exhibited the highest biodiversity, hosting all six recorded species. This pattern is consistent with general expectations from island biogeography: larger islands, with their broader range of habitats and more extensive networks of streams and rivers, tend to support a richer fauna. One species showed the most extensive distribution of all, occurring on nearly all surveyed islands—Amami-Oshima Is., Kakeromajima Is., Yorojima Is., Kikaijima Is., Tokunoshima Is., Okinoerabujima Is., and Yoronjima Is.—with Ukejima Is. being the sole exception. Such a broad distribution suggests that this species possesses considerable ecological tolerance and dispersal capability, enabling it to establish populations across a wide variety of insular environments.

In contrast, two species exhibited much more restricted ranges, occurring exclusively on Amami-Oshima Is. and Tokunoshima Is. The limitation of these species to only the two larger, higher, and more topographically complex islands may indicate specialized habitat requirements, a dependence

on particular stream types, or historical factors constraining their colonization of smaller islands. The remaining three species displayed intermediate distributions, occurring across several of the surveyed islands without reaching either the extensive occurrence of the most widespread species or the marked restriction of the localized ones. Together, these contrasting patterns illustrate the range of ecological strategies and distributional outcomes present even within a single insect family occupying a relatively compact archipelago.

These distribution patterns provide essential baseline data for understanding the ecological dynamics of black flies in the Amami Islands and offer valuable insights into their role within the natural environment. Documenting which species occur on which islands establishes a reference point against which future faunal changes—whether driven by climate change, land-use modifications, or biological invasions—can be measured. Moreover, because black fly larvae are sensitive indicators of freshwater quality, their distribution has direct implications for monitoring and conserving the islands' stream ecosystems. Continued research incorporating seasonal sampling, molecular identification, and analyses of environmental factors governing each species' occurrence will further clarify the processes shaping these distributions and strengthen the foundation for both biodiversity conservation and the management of medically and veterinarily important black flies in the region.

The Image Writing and Spiritual Perception of Clams in Yuan Dynasty Literature

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Abstract

From the Wei, Jin, and Northern and Southern Dynasties onward, literati, through their experience of tasting clams, expressed their personal feelings and philosophical reflections on life through the metaphor of objects. The Tang Dynasty saw further development in these sentiments, particularly in its profound consideration and concern for the "laborious" tribute of seafood such as clams and mussels. The Song Dynasty saw the addition of compassionate sentiments such as pity for fishermen, the release of captive animals, and abstaining from killing, along with a magnanimous philosophy of life, showcasing the Song Dynasty literati's spiritual characteristics of a fusion of Confucianism, Buddhism, and Taoism.

This thesis continues the research lineage mentioned above, further exploring the sentiments of literati expressed in the writings about "clams" in the Yuan Dynasty. It finds that Yuan Dynasty literati, living under the backdrop of foreign rule, frequent wars, and racial and class oppression, often used the clam's lustrous shell, delicate flavor, and shimmering inner pearl to symbolize their lofty character, their refusal to conform to worldly trends, and their talent that refused to be buried. They also used allusions such as "eating clams" and "mirages" to symbolize "seclusion," viewing worldly affairs as illusory, as spiritual symbols to resist the complex and harsh political situation. At the same time, while maintaining this noble "radiance," especially the remnants of the Song-Yuan transition, they did not forget their deep concern for the common people, shining with the brilliance of intellectuals fulfilling their social responsibilities.

Keywords: Imagery of “Clams”, Yuan Dynasty, Spiritual Perception, Personal Feelings, Philosophical Thinking

I. Introduction

To consolidate their rule, the Yuan authorities implemented a rigid system of ethnic and social stratification, dividing the population into four distinct classes: Mongols, *Semu* (Central and Western Asians), *Han* (Northern Chinese), and *Nan* (Southern Chinese). Government agencies were required to have Mongols as their heads, while *Han* and *Nan* individuals were restricted to subordinate roles—a clear reflection of how this unequal ethnic-class hierarchy manifested in official appointments. Meanwhile, the ruling class focused solely on plundering land and material wealth, neglecting cultural development; following the Yuan conquest of the Jin dynasty, the imperial civil service examination was held only once—in the ninth year of the reign of Ögedei Khan (Taizong)—and was subsequently suspended for nearly eighty years. This rendered scholars socially useless and relegated them to a lowly status; within the "ten ranks" of society codified during the Yuan era, they occupied the ninth tier—ranking below prostitutes (the eighth tier) and just above beggars (the tenth tier).

Amidst the darkness, chaos, and lack of avenues for official advancement that characterized the Yuan dynasty, did the sentiments projected by literati when observing "clams " represent a breakthrough beyond the traditions of the preceding dynasty? This is the focus of this article.

II. The Luster of the Clam Shell and Refined Flavor: A Noble and Upright Personality

Literati of the Yuan Dynasty continued the tradition—dating back to the Wei, Jin, and Northern and Southern Dynasties—of using the luster of a clam shell as a metaphor for one's own noble and upright character. There are also those who—following the tradition established by Su Shi of the Song Dynasty in his *Biography of the Jiangyaozhu* (江瑤柱,Pen-shell Adductor Muscle)—use the creature’s elegant flavor and its exacting choice of habitat as metaphors for their own noble character. A notable example is Bai Pu (白樸,1226–1306), who wrote in his *Shui Long Yin* (水龍吟,Song of the Water Dragon):

"Orchid flames spew rainbows; precious incense wafts with musk; jade-hued wine is strained of its dregs. Who else could recount in detail the elegance of days gone by—the taste of the *Jiangyaozhu* and lychees?" In his later years, while settled in Nanjing, Bai Pu reminisced about the splendor of the past with his friend Wang Wenqing by the Qinhuai River; through vivid descriptions of delicacies like the *Jiangyaozhu*, lychees, and fine wine, he contrasted these memories with the desolate reality before him, revealing the profound melancholy of a loyalist to the fallen dynasty and a sense that life is but a dream. The *Jiangyaozhu* demands a highly specific environment for growth: clear water, temperatures between 5°C and 20°C, stable salinity, gentle currents, and calm, shallow waters with a sandy-gravel seabed. By identifying himself with the *Jiangyaozhu*, Bai Pu not only likens his own noble integrity to the shellfish's exquisite flavor but also uses its fastidious choice of habitat to metaphorically express his own philosophy of reclusive withdrawal—a stance adopted in the wake of the dynasty's collaps.

III. The Radiance of the Oyster Pearl: Inner Brilliance and Unrecognized Talent

Song Dynasty writers frequently likened flawless, lustrous pearls to precious people or things. Yuan Dynasty writers continued this tradition, often employing the oyster pearl as a metaphor for such preciousness—most commonly representing human talent, whether in others or in oneself. The use of the pearl within the oyster as a metaphor for the self-became increasingly common—a distinctive feature of the Yuan Dynasty that set it apart from earlier eras. Many of the authors were loyalists of the fallen Southern Song; they used the image of a pearl buried in silt and sand to express their refusal to accept obscurity. A prime example is found in Zhao Wen's (趙文,1239–1315) poem *Peng Haiyue's Journey to the North*(〈彭海月北遊〉): "Startled from a dream, the pure excursion lost; / Like a bright pearl buried deep within the shell. / For ten years I have bowed to the moon in silent prayer, / While aging in the sands of Jiangnan, my brow deeply lined... / Should the immortals ask of the 'Man of Green Hills,' / See him sitting—white-haired, amidst the bleakness of late autumn." Through a stark contrast between "dream" and "reality," the poet praises his friend Peng Haiyue's impending journey to the north, while simultaneously giving voice to his own melancholy—stranded in the south, ailing and aged, with grand ambitions left unfulfilled. The image of the "bright pearl buried within the shell" symbolizes the poet himself—a talented individual languishing in obscurity, thwarted by a mediocre and straitened environment. Zhao Wen had studied under Wen Tianxiang(文天祥) in his youth and served on the staff of the anti-Yuan resistance; later, he formed close ties with Liu Chenweng and his son, establishing the "Green Hills Society" (青山社,*Qingshan She*) and adopting the moniker "Man of Green Hills" (*Qingshan Ren*) as he lived in reclusion rather than serving the Yuan regime. Thus, the poem's final couplet serves as a self-portrait, revealing his steadfast commitment to a life of eremitism and refusal to hold office. Meanwhile, imagery such as "white hair," "late autumn," and "bleakness" vividly captures the poignant state of mind of a Song loyalist—lonely, aging, and powerless in the wake of cataclysmic historical upheaval—creating a sharp contrast with the vast horizons awaiting his friend.

IV. Eating Clams: A Recluse's Desire to Shun Worldly Affairs

"Eating clams" represents a simple diet—sourced from the immediate environment—associated with a reclusive life by the water. In Song Dynasty literature, the act frequently alludes to two classic tales—the immortal "squatting on a turtle and eating clams" (「踞龜食蛤」,*Huainanzi*,淮南子) and Shen Zhaolüe (沈昭略)"eating clams" (「且食蛤蜊」,*History of the Southern Dynasties*,南史)—to convey an author's carefree, open-minded detachment from worldly concerns. Song literati elevated the clam—an ordinary, everyday food—into a cultural symbol of "spiritual liberation," using it to counter the petty intrigues and banal drudgery of the "vulgar officialdom." The situation for Yuan Dynasty literati was different; they faced the far more complex and harsh realities of "alien rule" and the "darkness of a chaotic era." Consequently, while their specific expressions varied, the mindset revealed through "eating clams" reflected a shared spirit of the times: using a food associated with the grassroots world to defy

the lofty power of the imperial court. Thus, eating clams became a collective spiritual symbol for Yuan literati, representing a "refusal to collaborate" and a "return to the essence of life."

A notable example is in Qiu Kui's (丘葵,1244-1333) poem "Leiluo"(磊落): "My upright heart is unknown to men, looking back, it is both lamentable and sorrowful. The cup is empty and the roasted meat is cold, I am a poor official, my teeth are missing and my head is gray, I am old and retired. Nine out of ten things are not satisfactory, I am over eighty years old, what can I do? If I had known that the world was as dark as lacquer, I would have been better off eating clams in the kitchen." After the fall of the Southern Song Dynasty, Qiu Kui lived in seclusion in his hometown of Xiaodeng (now Xiang'an District, Xiamen City), Zhongshan, refusing to serve foreign powers, calling himself the Old Man of the Fishing Rock, and focusing on writing. The first couplet expresses his noble unwillingness to compromise his principles and his loneliness in the face of historical upheaval. When he was over eighty years old, thinking that even geniuses like Du Fu and Han Yu seemed so powerless in the face of fate and old age, he felt even more disillusioned with the dark reality of the early Yuan Dynasty. He then chose to preserve his integrity and late-life virtue by eating clams, conveying the strong indignation of a remnant of a fallen nation in his resentment and regret.

V. Mirages as Towers and Pavilions: Illusory Prosperity Vanishes in an Instant

The idea that mirages are formed by the exhalation of clams originated in the Han Dynasty. For example, the "Records of the Grand Historian: Treatise on Celestial Offices" (《史記•天官書》)states: "Mirages by the sea resemble towers and pavilions, and the vast wilderness is filled with the vapors of palaces and pavilions. The clouds and vapors each resemble the mountains, rivers, and people where they gather." In the Song Dynasty, when skepticism was prevalent, although Su Shi's "Mirage of Dengzhou" (〈登州海市〉)and Shen Kuo's (1031-1095) "Dream Pool Essays" (《夢溪筆談》)questioned the theory of "mirages are formed by the exhalation of clams," many literati still used "mirages" as a theme, comparing their magnificent appearance and fleeting nature to ideal realms or illusory prosperity that vanishes in an instant, in order to express their personal feelings and aspirations.

As for the "mirage" depicted by Yuan dynasty writers, although it also presents these two completely opposite images, compared to the Song dynasty writers who valued personal career advancement and retreat, the Yuan dynasty writers focused more on personal thoughts of seclusion and anxieties about the lives of ordinary people. For example, Zhou Tingzhen (周霆震,1292-1379) in his poem wrote: "Mirages and towers vanish in the blink of an eye; in the desolate ruins, who will mourn the autumn insects? The thatched door of the roadside hut is closed; it is still the old man who planted vegetables back then." Zhou Tingzhen was a famous poet and writer of the late Yuan Dynasty who personally experienced the wars and social upheavals of the Yuan Dynasty. Therefore, his poems are full of anxiety and lamentation about the changes of the times. In the poem, he used "mirages and towers vanish in the blink of an eye" to describe the fleeting nature of the prosperous life of the past, which turned into ruins, showing the author's longing for a peaceful and stable life in a turbulent world. At the same time, by contrasting "the fleeting prosperity" with "the vegetable vendor who remains unchanged," the author praises the officials (Chen Yunzhong and Taihe Xuanchai) for their ability to defend the city, protect the people, and maintain their integrity amidst the surrounding bandits, thus enabling the people to continue their peaceful lives.

VI. Coastal Delicacies: Folkways and local products

The interaction between literati and the unique local products and customs can generate a so-called "sense of place," which in turn shapes a local image, reproduces local color, and conveys concern and reflection on local customs. Regarding aquatic products like clams, Yuan Dynasty literati produced more poems about these coastal delicacies than in previous dynasties, conveying their observations of local

customs, people, and officials. For example, Wang Feng (王逢,1319-1388) wrote "A Brief Introduction to Jiading in Summer"(〈簡夏嘉定〉): "A hundred miles of misty Wu region, I revisit this secluded place. Deep city doors are closed late; narrow harbors turn back boats. Clams open their shells at dusk, cotton leaves unfurl in the autumn fields. The people's customs have returned to simplicity, thanks to the wise governor." The poet revisited Jiading (Wu region), capturing the dynamic of clams opening their shells at dusk and the static of cotton leaves unfurling in the autumn fields. The abundance of seafood and agricultural products embodies the local prosperity and vitality. The last two lines of the poem naturally elevate the scene of peace and prosperity to praise for the local official. It is precisely because of such a wise and virtuous leader that the people, who had experienced war and turmoil, were able to return to their simple and honest ways. Through rich sensory imagery, the poem presents the peaceful and prosperous era of Jiading under the rule of Magistrate Xia, moving from distant to near and from scenery to emotion. It also reflects the strong yearning of intellectuals for a peaceful and tranquil life during the turbulent period of the late Yuan and early Ming dynasties.

VII. Conclusion

Yuan Dynasty literati, living amidst foreign rule, frequent wars, and racial and class oppression, often used the gleaming shell, delicate flavor, and lustrous inner pearl of clams as metaphors for their lofty character, refined taste, and talent that refused to be buried in obscurity. However, even in darkness, these literati did not merely lament their unfulfilled potential, but rather upheld their inner values and the truth of nature, maintaining their integrity and believing that by quietly accumulating their "light" (genuine talent and learning), they could withstand the test of time and the tides of history, and like the pearl within the clam, undergo a tremendous transformation or advancement.

Meanwhile, while upholding their noble integrity and radiant spirit, many scholars chose to use allusions like "eating clams" and "mirages"—symbols of detachment from worldly affairs and viewing prosperity as illusory—as spiritual symbols to resist their complex and adverse political circumstances. Even in their "seclusion" as commoners, these scholars still used clams, a coastal delicacy, to express their humanistic concern and observation of local customs and people, and to praise local officials, conveying their hopes for the people's well-being and the peace of the border regions, shining with the brilliance of intellectuals fulfilling their social responsibilities.

*This research was supported by the National Science and Technology Council (NSTC) of Taiwan under Grant No. 114-2410-H-019-008

A Comparative Study of Art Island Strategies: Naoshima Art Project and Shinan County's One Island-One Museum Policy

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Abstract

This study compares the Naoshima Art Project in Japan and Shinan County's One Island-One Museum policy in Korea as two representative art island strategies for regenerating island regions. While Naoshima is a private-led, concentrated model built around contemporary art, architecture, and the conversion of vacant houses, Shinan County is a public-led, archipelagic model that attempts to distribute museums, gardens, colors, and site-specific artworks across multiple islands. The study uses a qualitative comparative case approach and reviews prior studies, policy documents, and project descriptions. The comparison shows that art can transform an island's external image, create a distinctive tourism brand, and expand relational population. However, it also shows that tourism visibility does not automatically lead to resident income, population recovery, or settlement sustainability. The paper argues that Shinan County should learn not only from Naoshima's success but also from its limitations, especially the risk of weak local economic circulation and insufficient community-based operation. A sustainable art island policy should connect artistic placemaking with resident participation, ecological conservation, local entrepreneurship, and long-term management systems.

Keywords: Naoshima, Shinan County, art island, island regeneration, cultural tourism

Introduction

Island regions are increasingly exposed to population decline, aging, industrial restructuring, and limited accessibility. These problems are not simply demographic or economic; they also weaken community confidence and reduce the capacity of islands to reproduce their own cultural and social life. In this context, culture and art have been adopted as policy instruments for reimagining islands as places of experience, memory, and creative consumption. Cultural regeneration differs from conventional physical redevelopment because it seeks to reinterpret existing resources rather than replace them. Lee and Lee (2012) emphasize that urban regeneration through culture should move beyond visual improvement or construction-oriented projects and should consider local history, culture, and placeness before physical intervention.

Naoshima, located in the Seto Inland Sea, has become the most frequently cited Asian example of art-led island regeneration. Its transformation was driven by the Benesse Group's long-term investment, Tadao Ando's architecture, contemporary art museums, and the Art House Project in the Honmura district. Shinan County, by contrast, is pursuing an art island policy under very different conditions. It consists of more than one thousand islands, faces severe accessibility constraints, and has attempted to combine the One Island-One Museum project with color marketing, garden policies, marine tourism, and renewable energy benefit-sharing. This study asks how these two models are similar, how they differ, and what lessons Shinan County can draw from Naoshima.

Materials and Methods

This study adopts a qualitative comparative case study method. The cases were selected because both are island regions that use art as a strategic medium for regional regeneration, yet they differ in scale, governance, spatial structure, and development logic. Naoshima is a relatively concentrated, private-sector-led model centered on one island and a small number of symbolic art sites. Shinan County is a dispersed, local-government-led model that attempts to construct an archipelagic network of art, gardens, colors, and museums across many islands.

The analysis is organized around five dimensions: background of decline, governance structure, spatial strategy, cultural-tourism content, and sustainability. The main sources are prior academic studies on Naoshima and Shinan County, policy-related reports, and descriptive project materials. Shin and Park (2013) provide an important socio-economic reading of Naoshima by linking the island's population structure and industrial structure to the rise of culture and art tourism. Jeong and Lee (2018) offer a critical post-project assessment by examining population decline and vacant houses after the success of the art project. For Shinan County, Lee et al. (2018), Jo et al. (2021), Lee (2025), and Jeon (2024) provide useful perspectives on cultural art tourism, sustainable island tourism, garden-based island revitalization, and local sustainability.

Results

The first finding concerns the different origins of the two strategies. Naoshima's art project emerged from the decline of a manufacturing-centered island economy and from environmental damage associated with smelting industries. Shin and Park (2013) note that the copper smelter had long shaped Naoshima's industrial, demographic, and social structure. The later entry of the Benesse Group created a new cultural and tourism industry and gave the island a new image. In this sense, Naoshima is not merely a story of art replacing decline; it is a story of industrial restructuring in which a corporate actor transformed land, architecture, and art into a new spatial economy.

Shinan County's strategy emerged from a broader crisis of island depopulation and regional marginality. Jeon (2024) describes Shinan as a highly vulnerable island county with severe transportation constraints and low fiscal capacity, but also as a locality that has tried to create a new sustainability model through renewable energy benefit-sharing, color marketing, gardens, and cultural administration. In addition, Jo et al. (2021) argue that sustainable island tourism in Shinan should preserve island resources, use local uniqueness, strengthen resident agency, and return part of tourism benefits to local cultural development. These arguments indicate that Shinan's art policy must be understood within a wider framework of island sustainability, not only as a museum-building program.

The second finding concerns governance. Naoshima represents a private-led model. The Benesse Group played a central role in land acquisition, museum development, art programming, and brand formation. The local government and residents participated in parts of the process, but the symbolic and financial center of the project remained corporate. This structure allowed long-term investment and high-quality artistic control, but it also created questions about how much economic value circulated within the local community. Jeong and Lee (2018) show that even after Naoshima became an international art destination, its population continued to decline and vacant houses increased, suggesting that art-led tourism did not automatically solve settlement problems.

Shinan County represents a public-led model. The local government defines the policy vision, coordinates artists and experts, invests in public spaces, and links art projects with tourism and local branding. Its One Island-One Museum policy aims to make each island a distinctive cultural space. The interview-based policy material describes Shinan's ambition to develop each of its islands as an artistic place while preserving the natural environment. However, public leadership also involves risks. If residents remain passive recipients of projects, the policy may become an administrative display rather than a community-based regeneration process. Lee (2025) warns, through the case of the One Island-One Garden policy, that island revitalization requires local identity, resident participation, and a self-sustaining local ecosystem.

In comparative terms, Naoshima can be summarized as a concentrated art island model, while Shinan County can be summarized as a dispersed art archipelago model. Naoshima's main strength is global brand power supported by coherent artistic direction. Shinan County's main strength is policy integration across islands, gardens, colors, museums, and marine tourism. The main risk of Naoshima is

weak local circulation and continued depopulation, whereas the main risk of Shinan County is administrative dependency and a long-term maintenance burden.

Discussion

The comparison suggests that art island policy should be evaluated by more than visitor numbers, media visibility, or the reputation of participating artists. Naoshima demonstrates that art can radically transform the symbolic meaning of a declining island. The Benesse House Museum, Chichu Art Museum, Lee Ufan Museum, and the Art House Project created a unique relation among sea, light, architecture, and contemporary art. Kim and Lee (2020) interpret the Art House Project as a successful case in which vacant houses became exhibition spaces and produced material and non-material boundaries through interactions among nature, architecture, art, and viewers. This shows that the deepest power of art-led regeneration lies in spatial experience, not simply in installing artworks.

At the same time, Naoshima also reveals the limits of art-led regeneration. Jeong and Lee (2018) found that the island's population decreased substantially after the project period and that more than one hundred vacant houses or vacant lots were identified in field research. Their point is crucial: a place can become globally famous while still failing to secure local settlement sustainability. Therefore, Shinan County should not define success only as becoming "Korea's Naoshima." The more important task is to build a local circulation system in which artistic value leads to resident income, local entrepreneurship, cultural education, and long-term community ownership.

Shinan's advantage lies in its archipelagic diversity. Unlike Naoshima, which is centered on a compact set of art sites, Shinan can create differentiated island identities. A flower island, a piano island, a purple island, a sea museum, and a garden island can form a networked destination rather than a single flagship site. However, this advantage can become a weakness if each island is developed as an isolated spectacle. The policy needs a curatorial principle that links island ecology, local memory, resident narratives, and visitor experience. Lee et al. (2018) argue that Shinan's cultural-art resources should be connected with marine tourism through people-centered storytelling. This perspective is useful because it prevents art from becoming an external object imposed on the island.

The sustainability of Shinan's model also depends on governance after construction. Museums and art installations require maintenance, programming, transportation coordination, interpretation, and local service capacity. If the county government remains the only active operator, the model will be financially and institutionally fragile. Resident cooperatives, local guides, youth creators, small lodging businesses, food services, and cultural educators should be integrated into the operation. In this respect, the policy should be linked to renewable energy benefit-sharing, local festivals, and garden maintenance so that residents experience the project as an economic and cultural asset rather than as a symbolic public work.

Conclusion

Naoshima and Shinan County show two different pathways of art-led island regeneration. Naoshima is a private-led, concentrated, high-art model that transformed a declining industrial island into a global art destination. Shinan County is a public-led, dispersed, policy-integrated model that seeks to transform many islands into a cultural archipelago. Both cases demonstrate the value of art as a means of rebranding, placemaking, and tourism development. Yet the comparison also shows that artistic success and regional sustainability are not identical.

The central lesson for Shinan County is that the One Island-One Museum policy should move beyond the physical creation of museums and artworks. It should become a long-term island regeneration system based on resident participation, ecological conservation, local income circulation, and distinctive storytelling. Naoshima's success offers inspiration, but its limitations provide an equally important

warning. The future of Shinan's art island policy will depend on whether art becomes an external attraction for visitors or an internal resource for island communities.

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* This research was supported by the Regional Innovation System & Education(RISE) Glocal University 30 Project through the Jeollanam-do RISE Center, funded by the Ministry of Education(MOE) and the Jeollanam-do, Republic of Korea. (2026-RISE-14-001)

Closing the Regional Gap in Global Competence among University Students in an Island and Coastal Region

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Abstract

This study aims to examine students at M University, a Glocal University 3.0 institution in an island and coastal region of Korea, to assess how demographic variables and participation in extracurricular global competence programs relate to students' global competence. Among 367 students, global competence was measured with 24 items from the Global Citizenship Scale (Morais and Ogden, 2011) and the World Citizenship Scale (Chi and Sun, 2007). Univariate tests showed significant differences by gender, year, overseas residence experience, and program participation, but not by major. A multiple regression entering all variables together showed that only overseas residence experience and program participation remained significant independent predictors, while the gender and year differences appeared to reflect confounding with program participation rates rather than independent effects. Because program participation was voluntary rather than randomly assigned, these associations should not be read as causal effects.

Keywords: Glocal University 3.0; Global Competence; Extracurricular Programs; Island and Coastal Region; Regional Education Gap

1. Introduction

Higher education increasingly emphasizes cultivating global competence, a multidimensional capacity spanning knowledge, skills, attitudes, and values needed to understand and act on issues of global significance (Mansilla and Jackson, 2011; OECD, 2018). In Korea, a persistent regional gap places students outside the Seoul metropolitan area, and especially in island and coastal regions with limited educational infrastructure, at a disadvantage in global competence (Jin, 2013). In response, the Ministry of Education launched the Glocal University 3.0 initiative in 2023 to strengthen the global competitiveness of universities, regions, and students together (Ministry of Education, 2023). M University, located in Jeollanam-do, was selected for this initiative and operates extracurricular programs designed to build students' global competence. This study analyzed how (1) demographic variables and (2) participation in these programs relate to global competence among M University students.

2. Literature Review

Global competence has been conceptualized through several complementary frameworks, including Mansilla and Jackson's (2011) four core capacities and the OECD's (2018) four subdomains of knowledge, skills, attitudes, and values. Building on this, glocalization frameworks integrate global and local perspectives in higher education (Robertson, 1995), and empirical studies link direct overseas experience and program participation to stronger global or world-citizenship competence (Ayitey, 2018; Chi and Sun, 2007). This regional gap is measurable: the average monthly private-tutoring expense per student in Jeollanam-do was 320,000 KRW in 2024, less than half Seoul's 673,000 KRW, and the high-school tutoring participation rate was 53.6% in Jeollanam-do versus 74.7% in Seoul (Ministry of Data and Statistics, 2025a). Because private tutoring accounts for much of students' pre-university exposure to English and international content, this access gap likely compounds the broader global-competence disadvantage documented for non-metropolitan students (Jin, 2013), motivating institutional interventions such as Glocal University 3.0.

3. Methods

Participants were 367 undergraduate students at M University, recruited through convenience sampling via an online and paper-based questionnaire. The questionnaire measured gender, year,

major, overseas residence experience, and participation in extracurricular global competence programs, together with 24 global-competence items drawn from the Global Citizenship Scale (Morais and Ogden, 2011) and the World Citizenship Scale (Chi and Sun, 2007), rated on a 6-point Likert scale.

Because items were combined from two different scales, an exploratory factor analysis (EFA) was conducted to check construct validity before treating the items as a single measure. The KMO value was .953 and Bartlett's test was significant (χ^2 = 4877.32, p < .001). Three factors had eigenvalues above 1 (11.01, 1.66, 1.05), but Factor 1 alone explained 45.9% of variance, far exceeding Factor 2 (6.9%) and Factor 3 (4.4%), supporting a dominant single-factor structure; reliability was high overall (Cronbach's α = .947), though two two-item subfactors — global knowledge (α = .469) and glocal civic activism (α = .512) — fell below acceptable thresholds. A sensitivity analysis excluding these four items produced a 20-item mean nearly identical to the 24-item mean (r = .996) and reproduced the same pattern of significant results, so all analyses below use the mean of the original 24 items. Independent-samples t-tests and one-way ANOVA (with Welch correction where variances were unequal) tested group differences, and a multiple regression entering all variables simultaneously tested independent effects while controlling for confounding among variables.

4. Results

Table 1 summarizes the univariate results. Global competence differed significantly by gender, year, overseas residence experience, and program participation, but not by major (F = 1.01, p = .388, η^2 = .008). Gender, year, overseas residence experience, and program participation were also significantly associated with one another (e.g., gender and program participation, χ^2 = 200.158, p < .001, Cramér's V = .739; year and program participation, χ^2 = 131.982, p < .001, Cramér's V = .600), motivating a multiple regression to test whether each demographic difference held independently once program participation was controlled.

Table 1. Univariate Results by Demographic Variable

Variable	Group	*n*	*M(SD)*	Test statistic	*p*	Effect size
Gender	Male	183	3.69(0.57)	t = -12.51	<.001	d = 1.31
	Female	184	4.37(0.46)			
Year	1st	145	3.81(0.62)	Welch's F = 48.04	<.001	η^2 = .225
	2nd	97	4.35(0.48)			
	3rd	83	3.81(0.58)			
	4th	42	4.52(0.33)			
Overseas residence	No	332	3.94(0.58)	Welch's t = -18.96	<.001	d = 1.69
	Yes	35	4.88(0.22)			
Program participation	No	180	3.53(0.42)	t = -24.39	<.001	d = 2.55
	Yes	187	4.51(0.35)			
Major	Humanities and Social Sciences	102	4.00(0.68)	F = 1.01	.388	η^2 = .008 (n.s.)
	Education	63	3.99(0.64)			
	Science and Engineering	151	4.03(0.58)			
	Arts and Physical Education	51	4.17(0.59)			

Note. Games-Howell post hoc for year: 1st- and 3rd-year students scored significantly lower than 2nd- and 4th-year students (all p < .001); no significant difference between 1st and 3rd (p ≈ 1.000) or between 2nd and 4th (p = .081).

Because this cross-sectional design compared different year groups at a single point in time, the year differences may reflect cohort effects — differences in the characteristics of students who entered

in different years — or selective attrition of lower-competence students, rather than developmental change within students over time. The effect size for program participation (d = 2.55) also far exceeded the range typically reported in educational program intervention research (d = 0.2-0.8), suggesting that participants and non-participants may have differed substantially in pre-existing characteristics, consistent with a strong self-selection effect.

The regression model, entering all variables simultaneously, was significant, F = 83.59, p < .001, and explained 67.8% of variance in global competence (R^2 = .678, adjusted R^2 = .670), with variance inflation factors below 2.6 for all predictors. Only program participation (B = 0.970, p < .001) and overseas residence experience (B = 0.449, p < .001) remained significant independent predictors. Gender's effect became non-significant and reversed sign (B = -0.111, p = .058), and year's effect also disappeared, indicating that the univariate gender and year differences largely reflected confounding with program participation rates rather than independent effects. All 35 students with overseas residence experience had also participated in the extracurricular programs, producing near-complete separation between the two variables; the coefficient for overseas residence experience therefore reflects variation within program participants rather than a general effect and should be interpreted with this limitation in mind. Major showed no significant univariate difference, but a significant positive net effect emerged for arts and physical education relative to humanities and social sciences (B = 0.187, p = .003), a pattern the univariate test did not detect and that suggests a possible suppression effect.

5. Discussion and Conclusion

These findings suggest a positive association between the Glocal University 3.0 extracurricular programs and students' global competence, consistent with the initiative's goal of closing the metropolitan–non-metropolitan competence gap. Because program participation was voluntary, self-selection cannot be ruled out, so this association should not be interpreted as a causal program effect. The large gap linked to overseas residence experience supports the initiative's goal of providing overseas experience to all students, though this result's generalizability is limited by the near-complete overlap noted above. The suppression effect observed for major, visible only after controlling for the other variables, suggests the policy implication that these programs are not concentrated in specific majors remains reasonable but warrants further examination. Limitations include convenience sampling from a single university, self-report measures, and a cross-sectional design that cannot separate program effects from pre-existing student differences or cohort effects. Future research should compare multiple Glocal Universities and consider propensity score matching or a longitudinal design.

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* This research was supported by the Regional Innovation System & Education(RISE) Glocal University 30 Project through the Jeollanam-do RISE Center, funded by the Ministry of Education(MOE) and the Jeollanam-do, Republic of Korea. (2026-RISE-14-001)

Enriching the Concept of Island Socio-Ecological System (SES) and Small Island Occupation Resilience

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Abstract

This study aims to refine and enrich the concept of Island Socio-Ecological Systems (SES) through the Four-Dimensional Island Occupation Resilience Framework (4D-IORF), using Kisar Island in Southwest Maluku as an empirical case study. Conventional views rooted in the Theory of Island Biogeography often frame small islands (< 500 km^2) as isolated and fragile environments with severely constrained ecological buffer capacities. However, synthesizing multi-disciplinary evidence—spanning prehistoric zooarchaeology at Here Sorot Entapa (HSE) rockshelter, historical excavations at the fortified settlement of Negeri Lama Purpura (NLP), and modern agro-pastoral ethnography—demonstrates that long-term island habitation is dynamically sustained through social-ecological adaptive capacities. The 4D-IORF model integrates four core adaptive dimensions: Environmental Dynamics, Subsistence Adaptation, Technological Development, and Inter-island Connectivity. Findings reveal that initial terminal Pleistocene occupation (~15,500 cal BP) at HSE was maintained through specialized maritime foraging and an extensive obsidian exchange network across Wallacea that functioned as a spatial risk-buffering mechanism. When Early Holocene environmental instability breached localized adaptive thresholds, an occupational hiatus occurred (~9.5–5.0 ka BP), followed by mid-Holocene re-occupation (~5.0 ka BP) marked by technological restructuring and ceramic adoption. In historical and contemporary eras, socio-ecological resilience persisted through stone fort (lutur) construction, mutualistic integration of endemic Kisar sheep and local maize cultivation, and indigenous Hapa food governance institutions. This study formulates five theoretical propositions and identifies four dynamic occupational trajectories (persistence, reorganization, discontinuity, and reoccupation), offering crucial insights for integrating Local Ecological Knowledge and Nature-based Solutions into climate adaptation policy for Small Island Developing States (SIDS).

Keywords: Island Socio-Ecological System (SES), 4D-IORF Framework, Kisar Island, Here Sorot Entapa, Maritime Connectivity, Occupation Resilience.

1. Conceptual Foundation: From Island Biogeography to Island Socio-Ecological Systems (SES)

The analysis of human occupation dynamics on small islands has undergone a fundamental paradigm shift in recent decades. Conventionally, island archaeology and ecology were heavily influenced by the Theory of Island Biogeography formulated by MacArthur and Wilson (1967). This theory posited that small islands (particularly those with an area < 500 km^2) possess low biodiversity, severely constrained ecological carrying capacity, and high degree of isolation, rendering them ecologically marginal and incapable of supporting long-term human habitation without intensive agricultural foundations.

However, contemporary archaeological and social-ecological evidence challenges this deterministic view. Modern frameworks conceptualize small islands as Island Socio-Ecological Systems (SES) which is a complex adaptive systems that integrate biophysical subsystems (ecosystems) and human subsystems (social structure, technology, and governance) interacting through non-linear feedback loops (Folke, 2006; Talubo et al., 2022). Within an SES perspective, localized ecological constraints do not inevitably dictate vulnerability or occupational collapse. Human adaptive capacity—realized through maritime technology, subsistence diversification, mobility flexibility, and inter-island connectivity networks—effectively buffers the risks arising from terrestrial resource scarcity (O'Connor et al., 2018; Reepmeyer et al., 2019).

In this context, Kisar Island (Yotowawa) in Southwest Maluku Regency provides an exceptionally rich empirical and theoretical testing ground. Covering a land area of only ~81.15 km^2, Kisar is the smallest island in the Wallacean Archipelago with documented human occupation extending from the Late Pleistocene (~16,000 cal BP) to the modern historical era (Hawkins et al., 2024; Kaharudin et al., 2019, 2025). The integration of prehistoric archaeological excavations at Here Sorot Entapa (HSE) cave, historical cliff-top settlement excavations at Negeri Lama Purpura (NLP), and modern ethnographic and agro-climatological studies yields deep-time SES evidence on how small island systems manage vulnerability, resilience, and adaptive thresholds.

2. Bio-Physical and Ecological Characteristics of Kisar Island (Yotowawa)

Geologically, Kisar Island is situated at the boundary between the non-volcanic Outer Banda Arc and the volcanic Inner Banda Arc, approximately 25–30 km north of Timor-Leste (Kadarusman et al., 2010; O'Connor et al., 2019). The island consists of uplifted high-pressure metamorphic bedrock encased by five uplifted Quaternary coralline limestone terraces reaching elevations of up to 140 meters above sea level (Major et al., 2013). Due to its steep offshore bathymetry, Kisar's land area remained remarkably stable, experiencing minimal spatial expansion or contraction despite global sea-level fluctuations of up to 120 meters over the last 50,000 years of glacial-interglacial cycles (O'Connor et al., 2018).

The environmental setting of Kisar is defined by several extreme physical constraints:

a. *Semi-Arid Agro-Climatology*: Kisar is among the driest regions in Maluku, with annual rainfall ranging between 900–1200 mm/year. Approximately 80% of annual precipitation falls during a short 3-to-4-month rainy season (December–March), followed by a prolonged 7-to-8-month dry season (April–November) (Laimeheriwa, 2014; Risamasu et al., 2023).
b. *Karstification and Surface Water Scarcity*: Due to the highly porous limestone terrain, rainwater rapidly infiltrates deep aquifers, leaving the island devoid of permanent surface rivers. Dry-season freshwater relies exclusively on dug wells and natural karst springs (Pohjakas et al., 1976; Trainor, 2003).
c. *Terrestrial Faunal Depauperization:* Terrestrial fauna is severely depauperate, restricted to a few bat species, small rodents, lizards, snakes, and birds (Maryanto & Higashi, 2011; Monk et al., 1997). The complete absence of medium-to-large endemic terrestrial mammals in prehistoric deposits confirms that terrestrial animal protein was extremely scarce.
d. *Savanna Vegetation and Adaptive Flora:* Kisar's vegetation is dominated by shrub savanna, Palmyra palm (Borassus flabellifer / koli), Kusum tree (Schleichera oleosa / kesambi), and drought-resistant thorny shrubs adapted to limestone soils (Earl, 1841; Trainor & Verbelen, 2013).

3. Four Dimensions of Social-Ecological Adaptation (The 4D-IORF Framework)

To systematically analyze island occupation resilience, the Four-Dimensional Island Occupation Resilience Framework (4D-IORF) articulates four core adaptive dimensions that interact dynamically within the island system:

3.1 Dimension 1: Environmental Dynamics

Environmental dynamics establish the baseline structure of ecological opportunities and constraints. On Kisar, temperature shifts, precipitation variations, sea-level changes, and coral reef health directly alter resource availability and freshwater supply. When environmental stress exceeds an island's ecological buffering capacity, the energetic cost of sustaining human life escalates significantly (Kaharudin et al., 2019).

3.2 Dimension 2: Subsistence Adaptation

Subsistence adaptation acts as the ecological response mechanism. To overcome terrestrial faunal scarcity, prehistoric populations expanded coastal and marine foraging strategies. Evidence from HSE cave demonstrates intensive reef gleaning, pelagic and benthic fish capture, and targeted harvesting of mollusks, crabs, and sea urchins (echinoderms), supplemented by terrestrial micro-botanical resources (Alifah & Mahirta, 2021; Samper Carro et al., 2016).

3.3 Dimension 3: Technological Development

Technological development functions as an adaptive capacity multiplier. Physical tool innovations and technical knowledge enhance extraction efficiency and resource processing. Key archaeological markers at Kisar include:

a. *Maritime Technology*: Shell fishhooks crafted from Tectus niloticus dated to ~15,000 BP (O'Connor et al., 2011, 2019).
b. *Lithic Technology:* A material shift from chert dominance in Pleistocene strata to crystal quartz in Late Holocene layers.
c. *Food Processing Technology:* The introduction of earthenware ceramics at ~5,000 BP, facilitating thermal processing (boiling) of tubers (Alocasia, Amorphophallus) and sago (Metroxylon sagu) (Alifah, 2016).

3.4 Dimension 4: Inter-Island Connectivity

Inter-island connectivity serves as a social-ecological risk-buffering mechanism. The ocean is conceptualized not as an isolating barrier, but as a highway for interaction. Maritime trade networks, physical mobility, and inter-clan social alliances granted small island communities access to exotic raw materials (such as obsidian), technical knowledge, and spatial relocation options during severe local environmental crises or droughts (O'Connor et al., 2018; Reepmeyer et al., 2019).

4. Chronological Reconstruction Across Eras: HSE and Negeri Lama Purpura

Integrating archaeological evidence from Here Sorot Entapa (HSE) rockshelter and the historical cliff-top fortified settlement of Negeri Lama Purpura (NLP) allows a comprehensive chronological reconstruction of Kisar's human occupation across 16,000 years.

Chronological Phase	Climate and Environment	Subsistence and Fauna	Technology and Material Culture	System Outcome
16.0–14.5 ka BP*)	Post-LGM warming; sea-level rise and global temperature increase	Intensive coastal harvesting (fish, mollusks, Tectus niloticus)	Tectus shell fishhooks; presence of Group 1 exotic obsidian	Initial Persistence
14.5–12.8 ka BP	Bølling–Allerød phase; cooler and drier regional climate	Peak exploitation of reef fish, crabs, and sea urchins	Peak obsidian and chert lithic tools; shell bead production	Peak Occupation Intensity
12.7–9.5 ka BP	Younger Dryas andEarly Holocene transition; sea-level instability	Shifts in coastal fauna ratio; increased local rodent intake	Decline in lithic density; peak red ochre utilization in rock art	Decline and Reorganization
9.5–5.0 ka BP	Early Holocene climate warming; severe water and ecological stress	Unrecorded deposit in HSE site strata	No archaeological evidence of cultural activity at HSE cave	Occupational Hiatus (Abandonment)

5.0–1.6 ka BP	Mid-to-Late Holocene climate stabilization	Dietary diversification; introduction of tuber & sago boiling	Appearance of pottery; quartz dominance; absence of obsidian	Re-occupation and Restructuring
11th–19th C. AD**)	ENSO climate fluctuations; pre-colonial spice trade pressures	Maize, dryland rice, legumes; sheep, goat, buffalo husbandry	Stone wall fortifications (lutur); Ming/Qing ceramics; Indo-Pacific glass beads	Fortified Settlement Era (NLP)

4.1 Chronological Synthesis Table and Adaptive Dynamics

4.2 Key Analysis: Evidenced Through HSE and NLP Sites

a. *Significance of Prehistoric Obsidian Networks:* Portable XRF analysis by Reepmeyer et al. (2019) confirms that obsidian artifacts recovered at HSE belong to a single exotic source (Group 1) geochemical fingerprint identical to obsidian found at Alor (Tron Bon Lei) and Timor-Leste. This establishes that Kisar participated in extensive maritime exchange networks since ~15,000 BP, providing a spatial risk buffer against local resource crises.
b. *Rock Art and Ideological Connectivity:* Over 40 rock art sites discovered along Kisar's limestone cliffs (featuring boats, anthropomorphic figures, dancers, and Dong Son / Moko drum motifs) demonstrate strong ideological and ritual connectivity between Kisar, Timor, and the broader Wallacean region (O'Connor et al., 2018, 2020).
c. *Transition to the Fortified Settlement Era:* Excavations at Negeri Lama Purpura (NLP-1) by Kaharudin et al. (2025) reveal that demographic growth, endemic inter-island warfare, and regional trade expansion triggered a consolidation of small mobile bands into stone-fortified cliff-top settlements (lutur) during the 14th–15th centuries AD.

5. Complex Agro-Pastoral Systems and Local Ecological Knowledge (LEK)

In contemporary times, Kisar's social-ecological resilience is sustained by a highly adapted agro-pastoral system coupled with robust indigenous customary institutions.

5.1 Integration of Kisar Sheep and Local Maize Cultivation

A primary local genetic asset is the Kisar Sheep (officially recognized under Indonesian Ministerial Decree No. 2911/Kpts/OT.140/6/2011). This fat-tailed breed exhibits specialized evolutionary adaptations to dry, rocky limestone terrain (Salamena et al., 2006; Sangadji et al., 2024).

The sheep-maize system operates as a closed-loop mutualistic nutrient cycle:

a. Dry-Season Forage Supply**:** Maize crop residues (dried leaves and stalks) serve as the primary forage for sheep during the prolonged 7-to-8-month dry season when savanna pastures desiccate.
b. Soil Fertility Enhancement**:** Sheep manure is systematically collected by farmers and applied as organic fertilizer to enrich maize crops cultivated in limestone rock crevices

5.2 Crop Diversity and Indigenous Hapa Institutions

Alongside local maize (Var. Kuning Genjah), farmers cultivate pigeon pea (Cajanus cajan), mung bean, cassava, sweet potato, and the endemic Kisar Citrus (Agrinimal, 2018; Oldeman Agri Climate, 2024). Additionally, male villagers tap Palmyra palms (Borassus flabellifer / koli) to produce palm sugar and traditional fermented beverages (sopi).

Food security is governed through the customary institution of Hapa among the Meher and Oirata ethnic groups (Sahusilawane et al., 2015). Hapa regulates food distribution, enforces harvest prohibitions (local sasi), and mandates grain reserves for family famine relief during severe droughts.

5.3 Social Stratification and Ethno-Linguistic Dualism

Kisar's population is divided into two distinct ethno-linguistic communities:

a. Oirata (Woirata) People**:** Papuan-speaking (related to Fataluku in Timor-Leste), inhabiting the eastern district (Oirata Barat and Oirata Timur), recognized as the indigenous inhabitants.
b. Meher People**:** Austronesian-speaking, inhabiting seven traditional villages (Wonreli, Leklor, Abusur, Lebelau, Purpura, Nomaha, Kotalama), organized into patrilineal clans (soa) and ancestral houses (matarumah) (Pannell, 1991; Kaharudin et al., 2025).

Customary social structure features a tripartite caste system influencing land tenure and marriage endogamy: Marna (nobility / customary leaders), Wuhur (middle class / landholders), and Akha (commoners / workers) (Wattimury et al., 2022).

6. Theoretical Synthesis: Five Resilience Propositions and Policy Implications

6.1 Five Theoretical Propositions of 4D-IORF

Proposition 1 — Environmental Dependency: Human occupation sustainability on small islands is directly contingent upon a social system's capacity to adjust to changing ecological opportunities and local environmental constraints.

Proposition 2 — Subsistence Flexibility: Dietary diversification and cross-ecosystem utilization (marine, coastal, terrestrial) enhance adaptive capacity by mitigating reliance on any single vulnerable food resource.

Proposition 3 — Technological Amplification: Technological innovation (maritime gear, lithic transitions, ceramic processing) acts as an adaptive capacity multiplier, broadening extraction reach and food storage efficiency.

Proposition 4 — Connectivity-Mediated Resilience: Inter-island connectivity reinforces community resilience through physical mobility, exotic material exchange, social alliances, and spatial relocation options during local disasters.

Proposition 5 — Adaptive Threshold & Discontinuity: Small island occupation operates within adaptive thresholds. When cumulative environmental and social stress exceeds adaptive capacity, occupation undergoes decline, hiatus/abandonment (discontinuity), or reorganization via migration and re-occupation.

6.2 Formulation of Small Island Social-Ecological Resilience Index

Building on quantitative island resilience modeling (Parera et al., 2024; Talubo et al., 2022), the Social-Ecological Disaster Resilience Index (DRI) is formulated as a composite function of social, ecological, and economic indicators:

$$DRI = \sum (w_i \cdot I_ij)$$

Where w_i represents the relative weighting of indicator i (derived via Analytical Hierarchy Process or participatory weighting), and I_ij is the normalized score of indicator i for island j. Empirical studies by Parera et al. (2024) in Maluku confirm that high resilience index scores (DRI > 0.74) are achieved only when resource exploitation and conservation phases are governed through participatory, community-based management.

6.3 Implications for Nature-Based Solutions (NbS) and Small Island Governance

These findings yield critical policy directives for Indonesian small island governance (UNU-IAS, 2025; Frontiers in Environmental Science, 2025):

- **Strengthening Nature-Based Solutions (NbS):** Protecting coastal ecosystems (coral reefs and mangroves) and conserving endemic savanna flora (Schleichera oleosa and Borassus flabellifer) provides essential historical buffers against climate shocks.

- **Institutionalizing Local Ecological Knowledge (LEK):** Disaster risk reduction frameworks must formalize indigenous institutions (such as Hapa and integrated sheep-maize farming) into spatial planning, avoiding top-down, one-size-fits-all mandates.

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A Spatio-Temporal Model of Fishing Grounds Based on Local Knowledge: A Case Study of Haruku and Sameth Villages, Indonesia

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Abstract

Small-scale fisheries are closely connected to fishing grounds whose utilization may vary spatially and temporally. This study aimed to analysed temporal variations in the level and recurrence of fishing-ground utilization and to identify the spatio-temporal dynamics and utilization typology of fishing grounds in Haruku and Sameth Villages, Central Maluku, Indonesia. The study employed a spatio-temporal model based on local fishers' knowledge and field-based geospatial data. Initial fishing-ground identification was conducted through focus group discussions (FGDs) and participatory mapping, followed by field verification using GPS surveys. Temporal information was obtained through interviews with 25 fishers and organized into a January – December utilization calendar using a utilization score ranging from 0 to 3. The temporal data were used to calculate the Fishing Ground Utilization Level Index (ITP-DPI) and Fishing Ground Utilization Recurrence Index (IKP-DPI), which were subsequently combined to establish fishing-ground typologies. The results identified 11 fishing grounds with distinct utilization dynamics throughout the year. The number of active fishing grounds increased from two locations in January to March to one location in April, six locations in May, eight locations in June – September, and nine locations in October – December. Sair had the highest ITP-DPI (66.67%) and IKP-DPI (100%), whereas Jumur had the lowest ITP-DPI (8.33%) and an IKP-DPI of 25%. The typology produced four categories: high utilization – high recurrence, moderate utilization – high recurrence, moderate utilization – low recurrence, and low utilization – low recurrence. These findings indicate that fishing ground utilization characteristics vary among locations and cannot be understood solely from their geographic distribution but also require consideration of temporal dimensions. This model provides supporting information for understanding spatial utilization patterns in community-based fisheries management.

Keywords*:* fishing grounds, small-scale fisheries, local knowledge; spatio-temporal dynamics, utilization recurrence.

Educational Governance for Archipelagic Sustainability: Addressing Educational Inequality in Maluku through Secondary Data and Policy Analysis

Paul Arjanto

Abstract

This study examines how educational governance can respond to inequality in an archipelagic province where distance, island fragmentation, infrastructure constraints, and uneven institutional capacity shape educational opportunity. Focusing on Maluku, Indonesia, the study uses a secondary-data and policy- analysis design. Quantitative evidence is drawn primarily from Statistics Indonesia (BPS) publications for 2025–2026, including school participation, mean years of schooling, school availability, teacher qualifications, sanitation, and classroom conditions. These data are interpreted together with the Maluku Long-Term Regional Development Plan 2025–2045 and relevant national and international education policy frameworks. The findings show a distinctive inequality pattern. Basic-school participation is nearly universal, but participation falls sharply at ages 16–18, with a persistent urban– rural gap. Mean years of schooling vary substantially across the eleven regencies/cities, ranging from 8.74 years in South Buru to 12.37 years in Ambon. Infrastructure remains a governance concern: only 35.31% of primary-school classrooms, 42.05% of lower-secondary classrooms, 43.86% of upper-secondary classrooms, and 42.77% of vocational-school classrooms were classified as being in good condition in 2024/2025. At the same time, teacher qualification indicators are relatively strong, suggesting that Maluku's central challenge is not simply the aggregate supply of qualified personnel but their spatial deployment, institutional support, infrastructure, and the continuity of access across island clusters. Policy analysis indicates increasing recognition of archipelagic conditions, including affirmative access, distance learning, teacher and student accommodation, and strengthened vocational provision. The article proposes an Archipelagic Educational Governance Framework organized around island-cluster planning, geographic-equity financing, differentiated teacher deployment, resilient infrastructure, hybrid digital access, and place-based accountability. The study argues that educational sustainability in island regions requires governance to move from uniform administrative allocation toward geographically sensitive, data-driven, and multi-level coordination.

Keywords: educational governance; archipelagic sustainability; educational inequality; Maluku; secondary data; policy analysis; island education

1. Introduction

Educational inequality is often discussed as a difference in enrollment, attainment, learning outcomes, or resources between social groups. In archipelagic regions, however, inequality also has a spatial architecture. The physical separation of communities across islands changes the cost, continuity, and administrative complexity of providing education. A school system may appear adequately supplied at the provincial level while particular islands, coastal settlements, and remote subdistricts face long travel times, irregular transport, limited upper-secondary options, fragile infrastructure, and greater difficulty retaining teachers. Consequently, educational governance in an island region cannot be treated as a smaller version of governance on a continuous landmass. Geography becomes a constitutive variable in policy design rather than a background condition.

Maluku provides an important case for examining this problem. The province is organized across multiple islands and island groups, with Ambon functioning as a major administrative and educational center while other regencies contain dispersed settlements separated by sea. Such conditions generate what may be termed a geographic transaction cost of education: additional costs and risks associated with transportation, school construction and maintenance, teacher mobility, supervision, distribution of learning materials, digital connectivity, and student transitions between education levels. These costs

become especially consequential when students move from primary to lower-secondary and then to upper-secondary education, because the density of institutions declines as the education level rises.

The contemporary policy challenge is therefore not merely to expand the number of schools. It is to build a governance system capable of matching educational provision to differentiated territorial needs. This includes deciding where schools should be located, which services can be delivered through cluster arrangements, how teachers should be recruited and retained, how infrastructure should be maintained in coastal environments, how digital learning can complement rather than replace physical access, and how financing formulas should recognize distance and dispersion. These are management and governance questions because they concern allocation, coordination, accountability, institutional design, and the use of evidence in decision-making.

The relevance of this agenda is reinforced by Sustainable Development Goal 4, which commits governments to inclusive and equitable quality education and lifelong learning. The Education 2030 framework emphasizes that no education target should be regarded as achieved unless it is achieved for all, and it explicitly recognizes the need for qualified teachers, safe facilities, equitable access, and attention to vulnerable populations (UNESCO, 2016). In island contexts, these goals intersect with the broader sustainability agenda. Education affects the capacity of island communities to adapt economically, participate in environmental governance, develop maritime and coastal livelihoods, retain skilled human resources, and respond to climate and disaster risks. Conversely, an education system that systematically disadvantages remote islands can deepen territorial inequality and accelerate social and economic concentration in urban centers.

Recent research has increasingly recognized the distinctiveness of island education. Crossley and Sprague (2013) argue that small-island contexts offer important lessons for education for sustainable development because educational systems must operate under environmental, economic, and institutional constraints that are unusually visible. Telesford et al. (2024) similarly show that island context can be treated as an educational resource rather than merely as a disadvantage, particularly when curriculum, professional learning, and sustainability are connected to local realities. In Indonesia, research on remote islands has documented challenges involving teacher attendance, geographic mobility, uneven infrastructure, and the importance of socio-cultural conditions (Rochwulaningsih, 2015). More recent studies in Maluku and other archipelagic settings have highlighted the need for geographic justice, adaptive school management, digital support, and collaborative policy responses (Adriaansz, 2026; Pattiasina et al., 2026; Taufikurrahman et al., 2026).

Despite this growing literature, two analytical gaps remain important. First, discussion of educational disadvantage in archipelagic regions often relies either on localized case studies or on broad normative arguments. There is value in combining current official statistics with policy analysis to identify where the most visible pressure points lie across the education system. Second, educational inequality is frequently framed as a problem of access alone. Yet governance must also address the condition of infrastructure, teacher deployment, progression between levels, rural–urban differences, and the institutional mechanisms through which provincial and district governments coordinate responsibility.

This study addresses these gaps by examining educational inequality in Maluku through secondary data and policy analysis. It asks three questions: (1) What patterns of inequality are visible in current indicators of educational participation, attainment, institutional availability, and infrastructure? (2) To what extent do existing policy directions recognize the specific constraints of archipelagic education? and (3) What governance architecture is needed to convert policy recognition into more equitable and sustainable educational provision? The article is deliberately diagnostic and policy-oriented. It does not attempt to infer individual-level causality from aggregate data. Instead, it triangulates multiple

indicators to identify governance-relevant patterns and uses those patterns to formulate an archipelagic educational governance framework.

The paper contributes to educational management in two ways. Conceptually, it reframes geographic inequality as a governance problem involving the alignment of territory, resources, institutions, and accountability. Practically, it translates official data into a set of management priorities that can be used by provincial and district governments, school leaders, and higher-education partners. This is especially relevant to the theme of archipelagic sustainability because equitable education is both an outcome of sustainable regional development and an institutional condition for sustaining island communities over time.

2. Literature Review and Conceptual Framework

2.1 Educational governance, decentralization, and territorial inequality

Educational governance refers to the structures, rules, relationships, and decision processes through which education systems set priorities, allocate resources, coordinate actors, monitor performance, and ensure accountability. The concept is broader than administration. Administration concerns the execution of established procedures, whereas governance includes how responsibilities are distributed across levels of government and how state institutions interact with schools, communities, professional organizations, civil society, and other sectors. In decentralized systems, governance quality is particularly important because authority is dispersed and local capacity varies.

Indonesia's decentralization created substantial space for local governments to shape education services, but the relationship between decentralization and equity is not automatic. Kristiansen and Pratikno (2006) found that decentralization could coexist with social and geographical disparities when transparency, accountability, and fiscal capacity were uneven. Leer (2016) similarly showed that the effects of decentralization on educational outcomes depend on local institutional conditions, including school committees and teacher effort. More recent work indicates that fiscal decentralization can alter the relationship between education and inequality, again emphasizing that local institutional capacity matters (Siburian, 2024). These findings imply that an archipelagic province needs not only decentralized authority but also governance mechanisms that compensate for different territorial costs and capacities.

A conventional allocation model can inadvertently reproduce geographic inequality if it distributes resources using similar assumptions for fundamentally different places. For example, a uniform per-student allocation may be formally equal while being substantively unequal when the cost of transporting construction materials, providing teacher housing, supervising remote schools, or maintaining internet access is much higher on outer islands. Geographic equity therefore requires a distinction between equality of allocation and equity of opportunity. The latter may justify differentiated funding, staffing incentives, infrastructure standards, and service-delivery models.

2.2 Archipelagic sustainability and education

Archipelagic sustainability requires the long-term capacity of island communities to maintain social well-being, economic opportunity, environmental resilience, and institutional continuity despite geographic fragmentation and exposure to external shocks. Education is central to this process because it develops the human capabilities required for local leadership, public administration, health, entrepreneurship, environmental stewardship, and adaptation. In this sense, educational governance is not a sectoral issue isolated from regional sustainability; it is part of the institutional infrastructure of island development.

Small-island scholarship stresses that sustainability cannot be separated from place. Crossley and Sprague (2013) note that small states and island settings face distinctive environmental and

economic pressures but can also generate innovative educational approaches. Telesford et al. (2024) demonstrate how higher education can use island realities as a context for sustainability learning, workforce development, and inclusion. Gao et al. (2026) provide cross-national evidence that structural vulnerability and educational access interact in shaping progress toward SDG 4 in small-island developing states. Although Maluku is a subnational province rather than a sovereign SIDS, the analytical relevance is clear: geographic isolation, transport dependency, climate exposure, and limited scale can affect the feasibility and cost of educational provision.

An archipelagic perspective also changes how educational efficiency should be interpreted. A low student–teacher ratio or a small school may appear inefficient under a scale-based model, but it can be necessary to preserve access for a remote community. Conversely, concentrating all advanced services in a provincial capital may appear efficient administratively while imposing large private costs on families. Sustainable governance therefore requires a balance between economies of scale and territorial accessibility. Some services may need to remain local, while others can be organized through island clusters, boarding arrangements, mobile services, shared specialist teachers, or blended digital delivery.

2.3 From educational inequality to geographic educational justice

Educational inequality in Indonesia reflects multiple interacting factors, including household poverty, infrastructure, local administrative capacity, teacher distribution, school availability, and geographic remoteness. Recent syntheses emphasize that geography is not an isolated variable; it interacts with fiscal and institutional factors to shape access and quality (Listiawati & Sudianto, 2026). For remote islands, the consequences are cumulative. A student may face a local primary school but no nearby upper-secondary school, higher transport costs, weaker internet access, and fewer specialized teachers. Each transition increases the probability that spatial disadvantage becomes educational disadvantage.

The concept of geographic educational justice is useful because it asks whether people living in different places have a substantively fair opportunity to access and complete education. Pattiasina et al. (2026), focusing directly on Maluku, propose policy instruments including geographic-difficulty financing, teacher distribution based on island clusters, educational digitalization, local-wisdom and maritime-economy integration, and collaborative governance. The present study builds on this direction but anchors the argument in a current set of official indicators and links those indicators to a governance architecture.

Three dimensions are used as the analytical framework. The first is access and progression: whether students can enter and remain in education as they move through age groups and levels. The second is provision and quality conditions: the availability of schools, teachers, classrooms, sanitation, and other inputs that influence the feasibility of sustained learning. The third is governance responsiveness: whether policies and administrative arrangements explicitly recognize geographic variation and provide differentiated mechanisms to address it. Educational inequality becomes a governance problem when these dimensions are misaligned—for example, when formal access goals are universal but financing formulas, staffing systems, and infrastructure programs remain territorially neutral.

3. Methods

This study employed a descriptive secondary-data and policy-analysis design. The unit of substantive interest was the education system of Maluku Province, with disaggregation by regency/city where official data permitted. The design was selected because the research objective was to identify system-level patterns and governance implications rather than to estimate causal effects at the individual or school level.

The principal quantitative source was Statistics Indonesia (Badan Pusat Statistik/BPS), especially Statistik Pendidikan Provinsi Maluku 2025, released in May 2026, and Provinsi Maluku Dalam Angka 2026. These publications integrate the March 2025 National Socioeconomic Survey (Susenas) with administrative and sectoral education data. Indicators extracted for analysis included school participation rates (APS), net enrollment rates (APM), mean years of schooling, the number of schools by education level and regency/city, teacher qualification, student–teacher ratios, classroom condition, water access, and school sanitation. A separate BPS table on mean years of schooling by regency/city was used for spatial comparison.

The policy corpus centered on the Maluku Long-Term Regional Development Plan (RPJPD) 2025–2045, complemented by national education legislation and the UNESCO Education 2030/SDG4 framework. The RPJPD was selected because it establishes the province's long-horizon development direction and includes explicit measures related to education in island areas. These include affirmative access, distance learning through information and communication technologies, accommodation for students and teachers, strengthening open-school mechanisms, vocational education aligned with regional economic potential, and improvement of educator quality.

Quantitative analysis was descriptive. The study compared school participation by age and urban–rural residence, mapped inter-regional variation in mean years of schooling, summarized school availability, and examined infrastructure condition across education levels. Derived statistics were limited to transparent descriptive measures such as percentage-point gaps, range, mean, standard deviation, and coefficient of variation. No causal interpretation was assigned to these measures. For example, differences in mean years of schooling across regencies/cities were treated as indicators of spatial inequality, not as evidence that geography alone caused the differences.

Policy analysis followed a directed thematic approach. Policy statements were coded against five governance functions: access, resource allocation, teacher management, infrastructure and digital delivery, and accountability/coordination. The statistical findings were then triangulated with the policy themes. A governance gap was identified when an empirical pressure point was visible in the data but the policy mechanism was insufficiently specific regarding implementation, financing, institutional responsibility, or monitoring.

The study has several methodological limitations. BPS household-survey indicators are subject to sampling error and do not provide school-level causal evidence. Some administrative indicators are available only at the provincial level, which limits direct comparison of infrastructure quality among regencies. The number of schools is not a measure of accessibility unless considered together with population distribution and travel conditions. In addition, policy documents describe intended directions rather than verified implementation. These limitations are addressed by avoiding causal claims and by interpreting the data as a system-level diagnostic for governance design.

4. Results

4.1 Participation remains high in basic education but falls at upper-secondary age

Maluku's participation indicators show a clear progression problem. In 2025, the school participation rate was 99.56% for children aged 7–12 and 97.75% for those aged 13–15, but it declined to 77.28% for the 16–18 age group (BPS Provinsi Maluku, 2026a). The decline of more than twenty percentage points between the lower-secondary and upper-secondary age groups is one of the most important system-level signals in the data. It indicates that the core equity problem is not initial entry into schooling but continuity through adolescence.

The same pattern appears in net enrollment. The 2025 net enrollment rate was 95.29% at primary level, 77.02% at lower-secondary level, and 66.29% at upper-secondary/vocational level. Net

enrollment captures age-appropriate participation, so the decline suggests that delayed progression, dropout, non-entry, or grade-age mismatch become more significant at higher levels. From a governance perspective, this matters because expanding primary-school availability alone cannot resolve the bottleneck. The transition to secondary education requires attention to institutional location, transport, household costs, school relevance, and flexible delivery.

Urban–rural differences reinforce the territorial interpretation. At ages 7–12, urban and rural APS were both 99.56%. At ages 13–15, the urban rate was 99.16% compared with 96.70% in rural areas, a gap of 2.46 percentage points. At ages 16–18, the gap widened to 2.83 percentage points, with 78.77% in urban areas and 75.94% in rural areas. The absolute difference is not extremely large at the provincial scale, but the direction is consistent with BPS's own interpretation that upper-secondary facilities are more accessible in urban locations. Provincial averages can also conceal much larger differences among specific islands and subdistricts.

Gender patterns add nuance. Female APS exceeded male APS at ages 13–15 and 16–18, while male net enrollment was higher at primary and lower-secondary levels and female net enrollment was higher at upper-secondary level. These findings caution against a simple assumption that one gender is uniformly disadvantaged. Governance should therefore remain sensitive to the interaction of gender, age, locality, household economy, and school availability rather than relying on a single province-wide gender narrative.

Table 1. School participation rates by age group and residence, Maluku, 2025. Source: BPS Provinsi Maluku (2026a), Susenas March 2025.

Age group	Urban (%)	Rural (%)	Total (%)
7–12	99.56	99.56	99.56
13–15	99.16	96.70	97.75
16–18	78.77	75.94	77.28

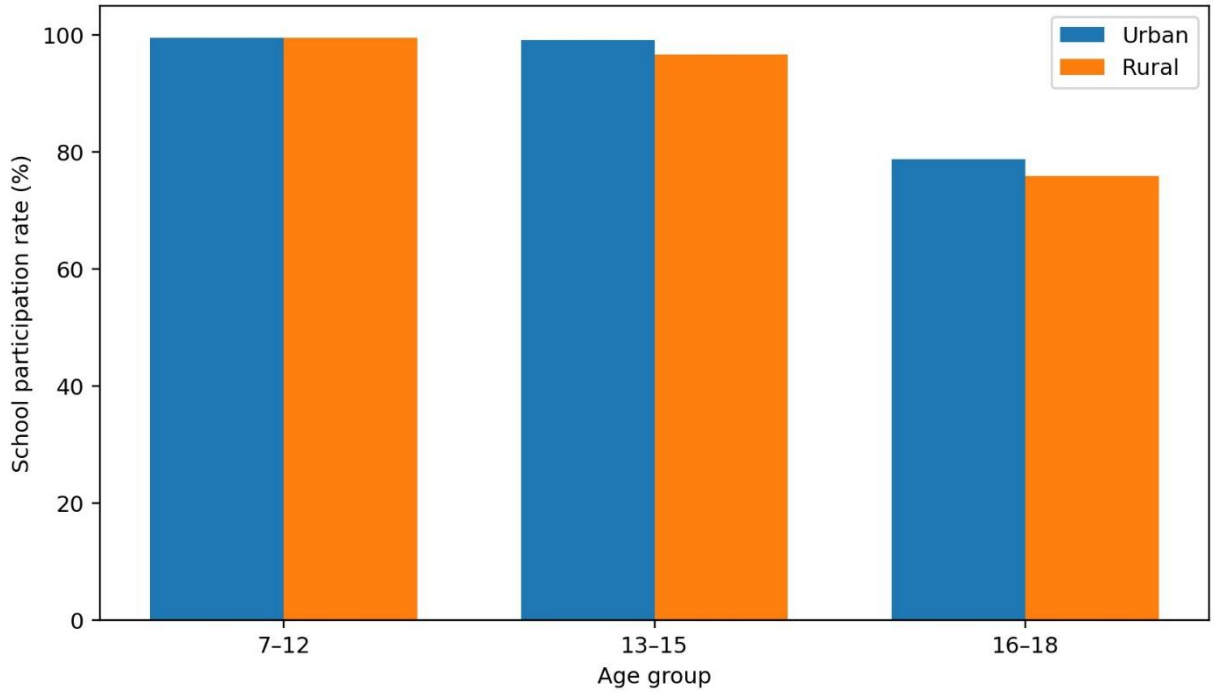


Figure 1. Urban-rural school participation in Maluku, 2025. Source: author's visualization of BPS data.

4.2 Inter-regional attainment disparities are substantial

Mean years of schooling provides a longer-run indicator of accumulated educational attainment and reveals substantial territorial variation. In 2025, the provincial figure was 10.51 years. Across the eleven regencies/cities, however, values ranged from 8.74 years in South Buru to 12.37 years in Ambon, producing a range of 3.63 years. The unweighted mean across the eleven jurisdictions was approximately 9.87 years, with a standard deviation of 0.93 and a coefficient of variation of 9.4%. These descriptive statistics are not population-weighted and should not be interpreted as an alternative provincial estimate; they simply summarize the dispersion among jurisdictions.

Ambon stands out with substantially higher mean schooling than every regency. Tual also exceeds the provincial figure at 10.68 years, while Maluku Tengah reaches 10.06 years. At the lower end are South Buru (8.74), East Seram (9.25), Buru (9.28), Southwest Maluku (9.39), and Aru Islands (9.46). This configuration is consistent with a center–periphery pattern in which the provincial capital and selected urban centers concentrate educational institutions and post-basic opportunities.

The policy significance of a 3.63-year inter-regional range is considerable. Mean years of schooling accumulates the effects of past access, transitions, household decisions, migration, and institutional availability. It cannot be reduced to current school supply. Nevertheless, persistent gaps imply that a uniform provincial strategy would start from highly unequal baselines. Districts with lower attainment may require stronger transition support, alternative pathways, targeted scholarships, student accommodation, and more aggressive upper-secondary and non-formal provision.

The pattern also supports the use of island-cluster governance. Administrative boundaries do not always correspond to the functional geography of service access. Some communities may be more effectively served through transport-linked island clusters, shared vocational centers, satellite learning hubs, or boarding arrangements than through a policy that assumes each district can independently reproduce a full range of educational services. The relevant question is not only how many schools exist in each jurisdiction, but whether students can realistically reach the next level of education at acceptable financial and travel cost.

Table 2. Mean years of schooling by regency/city in Maluku, 2025. Source: BPS Provinsi Maluku (2026b).

Regency/City	Mean years of schooling, 2025
Kepulauan Tanimbar	9.93
Maluku Tenggara	9.85
Maluku Tengah	10.06
Buru	9.28
Kepulauan Aru	9.46
Seram Bagian Barat	9.60
Seram Bagian Timur	9.25
Maluku Barat Daya	9.39
Buru Selatan	8.74
Ambon	12.37
Tual	10.68

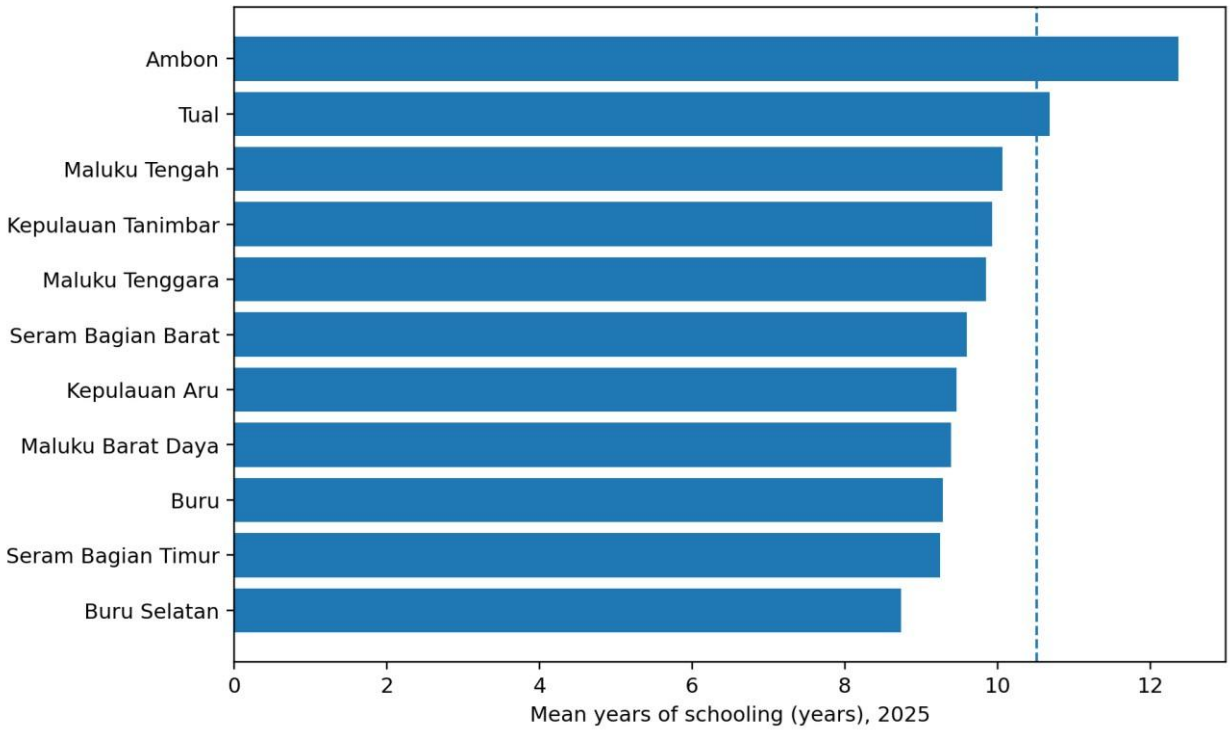


Figure 2. Inter-regional variation in mean years of schooling. Dashed line indicates the provincial value (10.51 years).

4.3 Institutional availability thins as education level rises

The administrative supply of schools also reflects the transition challenge. In academic year 2025/2026, Maluku had 1,844 primary schools, 718 lower-secondary schools, 295 upper-secondary schools, and 123 vocational schools under the Ministry of Primary and Secondary Education. The reduction in institution numbers as levels rise is expected because higher-level schools serve larger catchment areas. In an archipelagic province, however, catchment consolidation has a different meaning from consolidation on the mainland: the boundary between one catchment and another may involve sea travel rather than road travel.

Across districts, the pattern is highly uneven. Maluku Tengah had the largest number of primary (394), lower-secondary (149), and upper-secondary schools (82), while Ambon had 192 primary, 53 lower-secondary, 36 upper-secondary, and 19 vocational schools. The Aru Islands had 169 primary schools but only 12 upper-secondary and 6 vocational schools. South Buru had 107 primary schools, 49 lower-secondary schools, 15 upper-secondary schools, and 10 vocational schools. These counts should not be interpreted as simple adequacy ratios because district populations and settlement patterns differ. Their value is diagnostic: the progressively thinner institutional network can amplify geographic costs precisely at the age when participation declines.

Vocational provision is particularly important for archipelagic sustainability because regional economic development depends on skills relevant to fisheries, marine services, agriculture, tourism, renewable energy, logistics, and local enterprise. Yet vocational schools are the least numerous category. The governance challenge is therefore to avoid a binary choice between building a full vocational school in every locality and concentrating all vocational opportunity in cities. Shared training centers, mobile practice units, partnerships with industry and higher education, modular certification, and hybrid theory delivery can expand reach while maintaining quality.

Table 3. Number of schools by level and regency/city, academic year 2025/2026. Source: BPS Provinsi Maluku (2026a).

Regency/City	Primary (SD)	Lower secondary (SMP)	Upper secondary (SMA)	Vocational (SMK)
Kepulauan Tanimbar	119	66	21	9
Maluku Tenggara	145	51	16	11
Maluku Tengah	394	149	82	15
Buru	147	60	15	9
Kepulauan Aru	169	56	12	6
Seram Bagian Barat	207	93	41	17
Seram Bagian Timur	155	56	25	8
Maluku Barat Daya	155	58	21	12
Buru Selatan	107	49	15	10
Ambon	192	53	36	19
Tual	54	27	11	7

4.4 Infrastructure quality remains a major sustainability constraint

Classroom condition is one of the clearest infrastructure concerns. In academic year 2024/2025, only 35.31% of primary-school classrooms in Maluku were classified as being in good condition, compared with 42.05% at lower-secondary level, 43.86% at upper-secondary level, and 42.77% at vocational level. Severe damage affected 17.14% of primary classrooms, 14.77% of lower-secondary classrooms, 11.23% of upper-secondary classrooms, and 16.95% of vocational classrooms. Relative to national figures reported in the same BPS publication, Maluku's share of classrooms in good condition was especially low at upper-secondary and vocational levels.

Infrastructure in island environments carries distinct lifecycle costs. Buildings are exposed to salt air, humidity, heavy rainfall, storms, and difficult logistics for transporting materials and technical personnel. Maintenance therefore cannot be managed solely through periodic rehabilitation campaigns. A sustainable infrastructure system requires preventive maintenance, island-appropriate technical standards, asset-condition monitoring, and procurement mechanisms that recognize different transport and material costs.

Sanitation indicators reinforce the need for basic-service governance. BPS reported that 2.56% of primary schools had no water source in 2024/2025 and that only 41.12% of primary schools had separate toilets for male and female students, while 39.11% had no student toilet. Conditions were better at some higher levels but remained far from universal. These facilities are not peripheral to learning. They shape attendance, health, dignity, menstrual hygiene management, inclusion, and the overall safety of the school environment.

Teacher indicators present a more mixed picture. The proportion of teachers meeting the minimum S1/D4 academic qualification was high in 2024/2025: 91.17% at primary level, 97.38% at lower-secondary, 98.81% at upper-secondary, and 96.26% at vocational level. Province-wide student–teacher ratios also remained within the formal standards cited by BPS. This is an important finding because it suggests that the governance challenge should not be framed simply as an aggregate shortage of qualified teachers. The more relevant questions concern spatial distribution, subject specialization,

attendance, retention in remote locations, continuing professional development, and the capacity of schools to use available staff effectively.

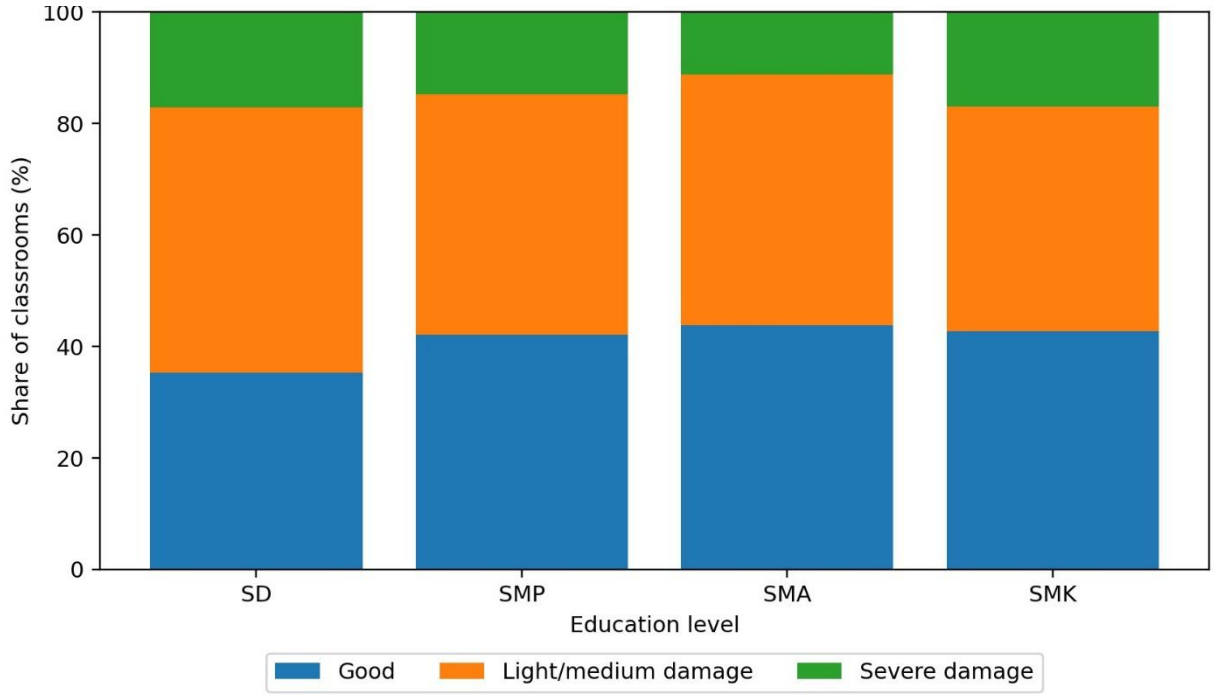


Figure 3. Classroom condition by education level, academic year 2024/2025. Source: author's visualization of BPS data.

4.5 Policy direction increasingly recognizes archipelagic constraints

The Maluku RPJPD 2025–2045 provides a stronger policy basis for archipelagic differentiation than a generic education plan would. Among its education directions are the acceleration of 13-year compulsory education; affirmative educational access for island areas that remain underserved; expansion of distance learning using information and communication technologies; provision of student and teacher accommodation; strengthening of open-school mechanisms; development of vocational education connected to regional economic potential; and improvement in the quality and adaptability of educators (Government of Maluku Province, 2025). These provisions are substantively aligned with the pressure points identified in the statistical analysis.

The strongest aspect of the policy is recognition that geographic disadvantage requires affirmative mechanisms. This moves beyond a purely universalistic formulation in which all regions receive the same program. Distance learning, accommodation, and open schooling acknowledge that physical access can fail in dispersed islands. The emphasis on vocational alignment also connects education to regional sustainability by recognizing fisheries, agriculture, mining, tourism, and other economic sectors.

However, the policy directions remain broad. The document does not by itself resolve several implementation questions: how geographic difficulty should be quantified in funding formulas; how island clusters should be defined; which level of government should finance teacher housing and transport; how digital learning should function in places with weak electricity or connectivity; how maintenance costs for coastal infrastructure should be calculated; or which indicators should trigger additional intervention. These are governance-design questions that require translation from strategy into operational rules.

The policy analysis therefore identifies a shift from recognition to institutionalization as the central challenge. Maluku has increasingly recognized the specific needs of island education, but sustainable implementation requires those needs to be embedded in budgeting, staffing, planning, procurement, data systems, and intergovernmental accountability. Otherwise, archipelagic language may remain a policy aspiration without changing the allocation mechanisms that shape daily educational opportunity.

5. Discussion

5.1 The principal inequality is continuity, not initial access

The combined evidence suggests that Maluku has made substantial progress in basic-school access but faces a pronounced continuity challenge. Near-universal participation among 7–12-year-olds and very high participation among 13–15-year-olds indicate that the education system reaches most children through primary and lower-secondary ages. The sharp decline at ages 16–18 changes the management problem. The priority is no longer merely to bring children into school; it is to keep adolescents connected to an appropriate pathway through the transition to upper-secondary, vocational, or equivalent education.

This transition is particularly sensitive to archipelagic geography. Upper-secondary schools are less numerous and their catchment areas are larger. Where travel requires boats, weather-dependent connections, or relocation to another island, the household cost of continuation rises. Direct tuition may not be the dominant barrier; transport, boarding, food, supervision, and opportunity cost can become decisive. This helps explain why policy instruments such as student accommodation and open schooling are especially relevant in Maluku.

Governance responses should therefore be organized around transitions rather than only around institutions. District and provincial education offices need transition-risk data: which lower-secondary schools feed into which upper-secondary institutions, how far students travel, where transport disruptions occur, which villages lack feasible daily access, and where dropout risk increases. Such data would permit targeted interventions before students leave the system.

5.2 Aggregate teacher adequacy can coexist with spatial teacher inequality

The teacher data reveal a common problem in education planning: aggregate adequacy does not guarantee spatial adequacy. High qualification percentages and favorable province-wide student–teacher ratios are encouraging, but they do not show whether mathematics, science, counseling, vocational, special-education, or digital-technology teachers are available in every island cluster. Nor do they show attendance reliability, turnover, or the burden placed on multigrade and small schools.

Research from Indonesian remote islands has long shown that teacher mobility can be disrupted by geographic conditions (Rochwulaningsih, 2015). In Maluku, the relevant management unit should therefore extend beyond head counts. A teacher-deployment dashboard should distinguish permanent residence, school assignment, subject specialization, certification, actual attendance, turnover, travel dependency, and housing availability. Incentives should be linked to verified geographic difficulty and professional support rather than treated as a uniform remote-area allowance.

Professional development also needs an archipelagic design. Conventional centralized workshops require travel and often remove teachers from schools for extended periods. A hybrid model could combine cluster-based in-person professional learning, mentoring from universities and master teachers, asynchronous modules that tolerate unstable connectivity, and periodic intensive residencies. Recent work in remote Maluku schools demonstrates the potential of practice-based digital capacity building when technology is adapted to local constraints rather than assumed to be continuously available (Arjanto et al., 2025).

5.3 Infrastructure should be managed as a resilience system

The classroom-condition data demonstrate that infrastructure quality is not a marginal issue. When fewer than half of classrooms at every level are classified as being in good condition, rehabilitation competes with expansion for limited resources. In an island province, postponing maintenance can be particularly costly because minor deterioration may accelerate under saline and humid conditions, while later repair requires expensive transport of materials and workers.

An archipelagic infrastructure strategy should therefore adopt lifecycle asset management. Each school should have a condition profile updated regularly, including structural integrity, roofing, water, sanitation, electricity, internet, accessibility, and exposure to coastal hazards. Maintenance funding should be triggered by risk and deterioration rather than waiting for severe damage. Design standards should reflect island conditions, including corrosion resistance, drainage, ventilation, rainwater management, and disaster resilience.

The same principle applies to digital infrastructure. Distance learning is frequently proposed as a solution to island remoteness, but it can reproduce inequality if connectivity and devices are unreliable. Digital governance should classify service levels by locality and specify fallback modes. High-connectivity schools can use synchronous learning; moderate-connectivity schools may rely on asynchronous platforms and downloadable content; low-connectivity schools may require offline servers, preloaded devices, radio, printed modules, or periodic content synchronization. Digitalization is therefore a portfolio of delivery modes, not a single platform.

5.4 Sustainability requires alignment between education and island economies

Archipelagic sustainability also requires that education remain relevant to the social and economic futures of island communities. If upper-secondary and vocational education is accessible only by leaving remote islands and offers qualifications disconnected from local opportunity, education may unintentionally contribute to permanent out-migration of skilled youth. Mobility is not itself a problem, but a sustainable regional strategy should also create credible pathways for graduates to contribute to island economies.

The RPJPD's emphasis on vocational education linked to fisheries, agriculture, tourism, mining, and other regional sectors is therefore strategically important. Implementation should go beyond opening study programs. Governance arrangements should connect schools with local employers, cooperatives, government technical agencies, ports, marine and fisheries institutions, universities, and community enterprises. Work-based learning and micro-credentials can be organized through island clusters, allowing students to develop locally useful skills without every school needing a complete set of expensive facilities.

This place-based approach is consistent with the wider literature on education for sustainable development in island settings. Island context can function as a learning resource, enabling students to engage with marine ecosystems, climate adaptation, food systems, renewable energy, disaster preparedness, culture, and community enterprise. Educational quality and sustainability can therefore reinforce one another when curriculum and school management are connected to place rather than merely compensating for geographic disadvantage.

5.5 From decentralization to coordinated multi-level governance

Decentralization creates both opportunity and fragmentation. District governments may understand local conditions better, but some problems exceed district boundaries or require provincial scale. Teacher distribution across island clusters, upper-secondary planning, vocational specialization,

digital backbone infrastructure, and transport-linked student accommodation are examples where coordination is essential. The appropriate governance model is therefore neither pure centralization nor isolated local autonomy.

A multi-level model would assign clear functions. National government should establish minimum standards, fiscal-transfer mechanisms, data architecture, teacher policy, and national digital infrastructure. Provincial government should coordinate cross-district island clusters, upper-secondary and vocational provision, specialized teacher deployment, infrastructure resilience standards, and tertiary partnerships. District governments should manage basic-education access, local transport and community linkages, school support, and granular data on out-of-school children. Schools and communities should contribute operational information, local accountability, and context-sensitive implementation.

Collaborative governance is particularly relevant where the education office does not control the infrastructure that determines access. Transport agencies, telecommunications providers, electricity agencies, public works, social services, disaster-management agencies, and village governments all influence the feasibility of education. Ansell and Gash's (2008) collaborative-governance framework emphasizes structured interaction, trust, shared understanding, and institutional design. In Maluku, this implies that educational equity should be treated as a cross-sector regional-development objective rather than a responsibility confined to the education bureaucracy.

6. An Archipelagic Educational Governance Framework for Maluku

Based on the statistical and policy findings, this study proposes an Archipelagic Educational Governance Framework built around six mutually reinforcing components. The framework is intended as a practical translation of geographic equity into education-system management. It does not require the creation of a new bureaucracy; rather, it requires existing planning, budgeting, staffing, infrastructure, digital, and accountability processes to use geographic evidence more systematically.

First, planning should be organized through functional island clusters. A cluster should be defined by actual transport connections, travel time, weather reliability, population distribution, and service catchments rather than administrative boundaries alone. Each cluster should have a minimum service map covering primary, lower-secondary, upper-secondary, vocational, special education, non-formal education, counseling, and digital support. Gaps should be classified as daily-access gaps, transition gaps, specialist-service gaps, or emergency-continuity gaps.

Second, financing should include a geographic-equity adjustment. The adjustment can combine distance from service centers, sea-transport dependency, settlement dispersion, construction logistics, connectivity constraints, and disaster exposure. The objective is not to reward remoteness but to prevent remote schools from being expected to deliver the same standards with structurally higher costs and identical nominal allocations. Funding formulas should be transparent and periodically reviewed using actual expenditure data.

Third, teacher governance should shift from aggregate head counts to differentiated deployment and retention. Island-cluster staffing plans should identify subject shortages, multi-school specialist needs, housing requirements, transportation support, and professional-development pathways. Incentives should be tied to location difficulty and length of service, while remote assignments should include reliable mentoring and career recognition. Shared specialist teachers and scheduled cluster visits can be used where full-time staffing is infeasible.

Fourth, school infrastructure should be governed as a resilient asset system. The province should maintain a geocoded asset register with condition ratings and maintenance histories. Priority should be

given to preventive maintenance, water and sanitation, electricity, corrosion-resistant construction, accessibility, and climate/disaster resilience. Infrastructure decisions should integrate school consolidation or expansion with realistic transport analysis so that efficiency measures do not unintentionally reduce access.

Fifth, digital access should follow a tiered hybrid model. Each locality should have a defined connectivity tier and an approved teaching-continuity package. This prevents policy from equating digital transformation with synchronous broadband-dependent learning. Offline-first platforms, downloadable resources, local servers, radio, printed materials, and periodic synchronization should

remain legitimate components of digital education where conditions require them.

Sixth, accountability should focus on geographic equity outcomes. Provincial reporting should disaggregate transition, dropout, attainment, teacher stability, infrastructure condition, and service availability by island cluster as well as by regency/city. A small set of equity indicators could include the share of 16–18-year-olds with feasible access to an upper-secondary pathway, average travel time to the next education level, teacher vacancy duration, percentage of schools with adequate water and separate toilets, classroom-condition index, and percentage of remote schools meeting minimum digital-continuity standards.

Together, these components create a governance cycle: geographic evidence informs differentiated planning; differentiated planning informs funding and staffing; funding and staffing support resilient service delivery; and disaggregated accountability reveals whether spatial gaps are narrowing. The cycle is compatible with the RPJPD but makes its archipelagic commitments more operational.

Table 4. Proposed Archipelagic Educational Governance Framework.

Governance component	Core problem	Operational mechanism	Illustrative indicator
Island-cluster planning	Administrative boundaries do not match service geography	Travel-time and transport-based education service maps	Share of communities with feasible access to next education level
Geographic-equity financing	Uniform allocations ignore island cost differentials	Difficulty index in grants, maintenance, and transport support	Per-student funding adjusted for geographic cost
Differentiated teacher deployment	Aggregate ratios conceal subject/location shortages	Cluster staffing plans, housing, incentives, shared specialists	Vacancy duration and teacher turnover by cluster
Resilient infrastructure	High classroom damage and costly island maintenance	Lifecycle asset management and island-appropriate standards	Share of classrooms in good condition
Tiered hybrid digital access	Broadband assumptions exclude low-connectivity areas	Online, asynchronous, offline-first, and printed fallback modes	Remote schools meeting continuity standard
Place-based accountability	Provincial averages conceal spatial inequality	Equity dashboard by island cluster	Transition, dropout, attainment, access and infrastructure gaps

7. Policy and Management Implications

The first immediate implication is to prioritize the 16–18 transition. A province-wide transition map should identify every lower-secondary school and the upper-secondary or vocational pathways realistically available to its graduates. Students whose next institution requires relocation or unreliable sea transport should be eligible for targeted boarding, transport, scholarship, or blended-learning support before they leave Grade 9. This would operationalize the RPJPD commitment to affirmative access.

Second, infrastructure rehabilitation should be paired with preventive maintenance. The current classroom-condition profile indicates that a rehabilitation-only approach risks a recurring backlog. A multi-year maintenance program with protected funding, local technical partnerships, and condition-

based prioritization is likely to be more sustainable. Water and student toilets should be treated as minimum service standards and monitored publicly.

Third, the province should build a teacher-distribution information system that moves beyond formal assignment. Data should capture subject, school, island cluster, actual service presence, housing, years in post, and professional-development access. Higher-education institutions in Maluku can support remote teacher development, school leadership coaching, action research, and digital-content production through sustained partnerships rather than one-off training events.

Fourth, vocational governance should be regionalized around economic clusters. Not every school needs every specialization. A maritime cluster, for example, can combine theory delivered in multiple schools with shared practical facilities, industry placement, and periodic intensive training. Similar arrangements are possible for tourism, agriculture, renewable energy, logistics, and digital entrepreneurship.

Fifth, monitoring should include geographic service indicators alongside conventional enrollment statistics. Provincial averages are useful for national comparison but insufficient for managing island inequality. Travel time, weather-related school disruption, island connectivity, teacher turnover, and the cost of reaching the next education level are governance variables and should become part of the evidence base.

8. Limitations and Future Research

This study is based entirely on secondary data and document analysis. It therefore cannot establish causal relationships between geographic conditions and individual educational outcomes. The observed association between urban location and higher participation, for example, may also reflect income, parental education, labor-market conditions, migration, and other unobserved factors. Future research should combine administrative data with geospatial travel-time analysis and household-level socioeconomic variables.

Second, several important governance variables are not available in the published datasets used here, including teacher attendance by island, subject-specific vacancies, student travel time, transport cost, internet reliability, and school-level maintenance expenditure. Collecting these variables would substantially improve policy targeting. A geocoded education-service atlas could be particularly valuable for Maluku.

Third, policy documents indicate intended direction rather than implementation quality. Future studies should examine how the RPJPD commitments are translated into annual budgets, sector plans, teacher policies, infrastructure procurement, and district-level programs. Comparative case studies across island clusters could identify which governance arrangements are most effective under different geographic conditions.

Finally, this article focuses mainly on access, attainment, staffing, and infrastructure. Learning outcomes are equally important. Future work should integrate Rapor Pendidikan or other assessment data, while carefully accounting for school size and socioeconomic context, to determine whether geographic inequalities in access are compounded by inequalities in learning quality.

9. Conclusion

Educational inequality in Maluku is not well described as a simple shortage of schools or teachers. The official data reveal a more complex pattern: basic-school participation is high, but participation and age-appropriate enrollment weaken at higher levels; mean years of schooling vary markedly among regencies and cities; the institutional network becomes thinner as education level rises; and a large share of classrooms require repair. At the same time, teacher qualification levels are relatively strong at the provincial scale. These conditions point to a governance challenge centered on spatial distribution, transition continuity, infrastructure resilience, and the capacity to convert aggregate resources into equitable island-level opportunity.

Maluku's long-term development policy increasingly recognizes these realities through affirmative access, distance learning, accommodation, open schooling, vocational alignment, and educator development. The next step is institutionalization. Archipelagic considerations need to be embedded in formulas, staffing rules, asset management, digital standards, service maps, and accountability indicators.

The proposed Archipelagic Educational Governance Framework responds to this need through six components: island-cluster planning, geographic-equity financing, differentiated teacher deployment, resilient infrastructure, tiered hybrid digital access, and place-based accountability. Its central premise is that equal treatment of unequal geographies can reproduce inequality. Sustainable educational governance therefore requires differentiated mechanisms that guarantee comparable educational opportunity across different island contexts.

For Maluku, this shift is strategically significant beyond the education sector. A more equitable education system strengthens human capability, local leadership, workforce development, social cohesion, and community resilience. In that sense, educational governance is not only a mechanism for delivering schooling; it is part of the institutional foundation for the sustainable future of island regions.

Declarations

Ethics statement: The study used publicly available aggregate secondary data and policy documents and did not involve human participants or identifiable personal data; therefore, institutional ethical approval was not required.

Funding: No specific external funding was received for this study.

Conflict of interest: The author declares no conflict of interest.

Data availability: All quantitative data analyzed in this article are available from official BPS publications and statistical tables cited in the references.

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From Extractivism to Ecological Restoration: An Ecotheological Perspective on Ecological Justice in Oil Palm Plantations in Latea, Maluku, Indonesia

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Abstract

The expansion of oil palm plantations into customary territories raises critical questions about economic development, community livelihoods, ecological degradation, and ecological justice. This article examines the socio-ecological dynamics of oil palm plantation development in Latea, Central Maluku, Indonesia, and critically evaluates the implementation of the Protestant Church of Maluku's (Gereja Protestan Maluku, GPM) solidarity-liberative ecotheological advocacy model. Adopting an evaluative research approach, the study draws on field-based empirical data gathered from customary and community leaders, local residents, church leaders, plantation workers, and other relevant stakeholders. The findings reveal an ambivalent socio-ecological reality. While oil palm plantations provide employment, household income, and educational opportunities, community accounts also identify deforestation, water-related problems, flooding, declining riverine vegetation, pressures on wildlife, and concerns about long-term ecological sustainability. Furthermore, the implementation of GPM's solidarity-liberative advocacy model has not consistently followed its intended stages, indicating a gap between its normative commitments and advocacy practices. Drawing on ecological justice, integral ecology, liberation ecotheology, and ecological restoration, this article proposes Just Ecological Restoration as a contextual development of solidarity-liberative ecotheology. The proposed model integrates ecosystem recovery with distributive, procedural, and recognition justice; intergenerational responsibility; respect for more-than-human life; livelihood diversification; and ethical-theological transformation. The article argues that ecotheological advocacy in extractive contexts must move beyond resistance alone toward the restoration and regeneration of just, sustainable, and mutually sustaining social-ecological relationships. In this framework, ecological restoration is not merely a technical intervention but also an ethical, theological, and socio-political commitment to the flourishing of human communities and the wider community of life.

Keywords: ecological justice; ecotheology; ecological restoration; extractivism; solidarity-liberative; oil palm; Latea

Reconstruction of a Model for Resolving Cases of Sustainable Marine Resource Violations Based on Local Wisdom in Maluku

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Abstract

Local wisdom is one of the vital sectors that must be preserved by the Indonesian people. One example is the local wisdom in Maluku, which has long been practiced in the management and protection of natural resources, including the resolution of marine resource violation cases. The model for resolving marine resource violation cases that has existed and been settled at the community level—known as *restorative justice*—is a form of local wisdom that needs to be identified and revitalized because it is rooted in community culture. This study aims to examine and analyze the construction and forms of resolving marine resource violation cases based on local wisdom in relation to the enactment of Law Number 1 of 2023 concerning the Criminal Code. This research employs a socio-legal research method, an approach that explores and investigates a problem not merely through the study of relevant legal norms or doctrines, but also by comprehensively examining the context of those norms and their enforcement. The findings reveal that when disputes or conflicts over marine resource management are deliberated through customary councils (*kerapatan adat*) or gatherings of traditional elders, it essentially constitutes a manifestation of the living law in society (*living law*) as an implementation of Article 2 of Law Number 1 of 2023. If the conflict escalates, causes substantial losses, and fails to reach a consensus, the matter may be escalated to the realm of national law.

Keywords: Local Wisdom, Marine Resources, Sasi

Weed Vegetation Analysis and Ecological Dominance in Immature and Mature Clove Plantations (*Syzygium aromaticum* L.) in Hila Village, Central Maluku

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1. Introduction and Background

Clove (Syzygium aromaticum L. Merr. & Perry), belonging to the family Myrtaceae, represents one of the most vital historical and economic perennial plantation crops in Maluku Province, Indonesia. Known historically as the epicenter of the global spice trade, the Maluku islands—particularly Ambon Island and the surrounding Central Maluku Regency—continue to rely on clove smallholdings as a primary driver of rural agrarian livelihoods and regional economic stability (Riry & Tanasale, 2019; Luhukay & Mahulete, 2020). Among the traditional clove-producing centers in Leihitu District, Hila Village stands out for its extensive agroforestry systems, where clove trees are cultivated across varying terrain ranging from coastal lowlands to undulating hillsides.

Despite its high commercial value, clove productivity in smallholder plantations remains constrained by complex agroecological factors, among which weed competition poses a severe biophysical challenge. Weeds act as aggressive interspecific competitors that intercept essential microclimatic resources, including soil moisture, macro- and micronutrients (nitrogen, phosphorus, potassium), physical growing space, and photosynthetically active radiation (PAR) (Holm et al., 1977; Sastroutomo, 1990). In perennial crop ecosystems, the intensity and nature of weed competition evolve dynamically across the crop developmental continuum.

In immature clove plantations (Tanaman Belum Menghasilkan / TBM), young saplings possess limited root architecture and open, sparse canopy structures. This allows high solar radiation transmittance to the forest floor, stimulating rapid germination and aggressive proliferation of heliophilic annual broadleaves and fast-growing C4 grasses. Conversely, mature clove plantations (Tanaman Menghasilkan / TM) develop closed, dense overlapping canopies that intercept up to

85–90% of incoming light. This canopy closure significantly alters the microclimate by reducing soil surface temperatures, elevating relative humidity, and filtering light quality towards shade-adapted sciophilous perennial species (Tanasale et al., 2021). Understanding these ecological dynamics is crucial for developing sustainable agronomic practices.

2. Research Gap

Although general principles of weed ecology in tropical plantation crops (such as rubber, oil palm, and cocoa) are well documented, empirical quantitative research specifically examining weed floristic composition and structural dominance shifts in clove agroecosystems in Maluku remains remarkably sparse. Most local weed management practices in Hila Village rely on uniform, non-selective chemical spraying or un-targeted manual slashing without prior knowledge of the dominant weed species or community structural parameters. This non-targeted approach often leads to secondary weed outbreaks, herbicide resistance, unnecessary labor expenditure, and soil degradation.

Furthermore, there is a critical lack of comparative data measuring how canopy closure between immature (TBM) and mature (TM) growth stages influences species dominance ratios (SDR) and community similarity indices in Central Maluku spice agroforestry. Bridging this empirical gap is essential to transition smallholder farmers from reactive weed clearing to ecologically grounded Integrated Weed Management (IWM).

3. Research Questions

Core Research Questions Addressed in This Study:

RQ1: How does weed species richness and floristic composition differ between immature (TBM) and mature (TM) clove plantations in Hila Village?
RQ2: Which specific weed species exhibit ecological dominance across TBM and TM growth stages based on quantitative Summed Dominance Ratio (SDR) metrics?
RQ3: What is the degree of floristic similarity between weed communities across crop maturity stages, and what are the implications for stage-specific Integrated Weed Management (IWM)?

4. Methodology

4.1 Study Location and Environmental Setting

This research was conducted in smallholder clove plantations located in Hila Village, Leihitu District, Central Maluku Regency, Indonesia. The study area lies in a humid tropical maritime zone characterized by an average annual rainfall of 2,500–3,200 mm, mean ambient temperature of 26.5°C, and relative humidity ranging from 78% to 86%. Soils are predominantly Inceptisols with medium organic carbon content.

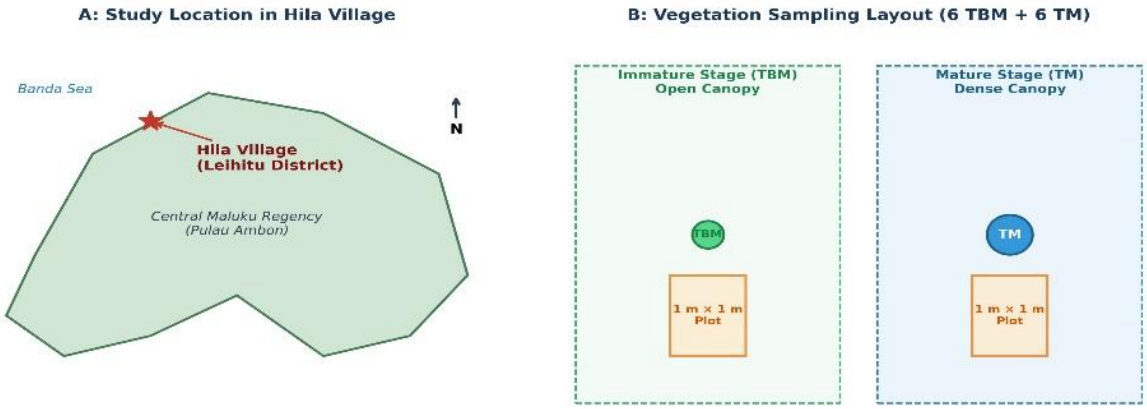


Figure 1: (A) Geographic location of the study site in Hila Village, Leihitu District, Central Maluku Regency, Pulau Ambon. (B) Schematic illustration of 1 m × 1 m vegetation sampling plots placed under immature (TBM) and mature (TM) clove tree canopies.

4.2 Vegetation Sampling Procedure

A field survey method utilizing square quadrat frames of 1 m × 1 m (1 m^2) was employed to systematically sample understory weed vegetation. Sampling plots were established directly under six representative immature clove trees (TBM, tree age 3–5 years, open canopy) and six representative mature clove trees (TM, tree age 15–20 years, dense closed canopy), yielding a total of 12 primary sampling units. Within each 1 m^2 quadrat, all weed individual plants were identified to species level, counted, and recorded.

4.3 Quantitative Vegetation Analysis Formulae

Floristic structure and ecological significance were evaluated using standard quantitative vegetation metrics (Mueller-Dombois & Ellenberg, 1974; Sastroutomo, 1990):

1. Relative Density (RD) & Relative Frequency (RF):
RD (%) = (Absolute Density of Species i / Total Density of All Species) × 100
RF (%) = (Absolute Frequency of Species i / Total Frequency of All Species) × 100
2. Summed Dominance Ratio (SDR):
SDR (%) = (Relative Density + Relative Frequency + Relative Dominance) / 3
3. Sorensen's Coefficient of Community (CC):
CC (%) = [2w / (a + b)] × 100
where: a = total species in TBM, b = total species in TM, w = number of species common

5. Results And Discussion

5.1 Species Richness and Floristic Structure

Field identification revealed a total of 36 distinct weed species across both plantation stages in Hila Village. In immature clove plantations (TBM), species richness was markedly higher, registering 28 weed species belonging to 14 botanical families. In contrast, mature clove plantations (TM) harbored 23 weed species across 12 families. The higher floristic diversity in TBM stands is directly attributable to the open canopy structure, which permits high light infiltration and fosters diverse pioneer broadleaves (e.g., Ageratum conyzoides, Synedrella nodiflora, Bidens pilosa) alongside annual grasses.

Table 1. Comparison of Summed Dominance Ratio (SDR) and growth forms of major weed species in immature (TBM) and mature (TM) clove plantations in Hila Village

No	Weed Species Name	Family	TBM SDR (%)	TM SDR (%)	Growth Form
1	*Cyrtococcum oxyphyllum*	Poaceae	**15.70**	**16.36**	Perennial Grass
2	*Oplismenus compositus*	Poaceae	9.45	11.20	Shade Grass
3	*Ageratum conyzoides*	Asteraceae	8.20	3.80	Broadleaf Herb
4	*Centotheca lappacea*	Poaceae	6.80	8.50	Perennial Grass
5	*Paspalum conjugatum*	Poaceae	5.90	4.10	Stoloniferous Grass
6	*Axonopus compressus*	Poaceae	5.10	3.40	Mat-forming Grass
7	*Other 22–27 Species*	Various	48.85	52.64	Mixed Flora

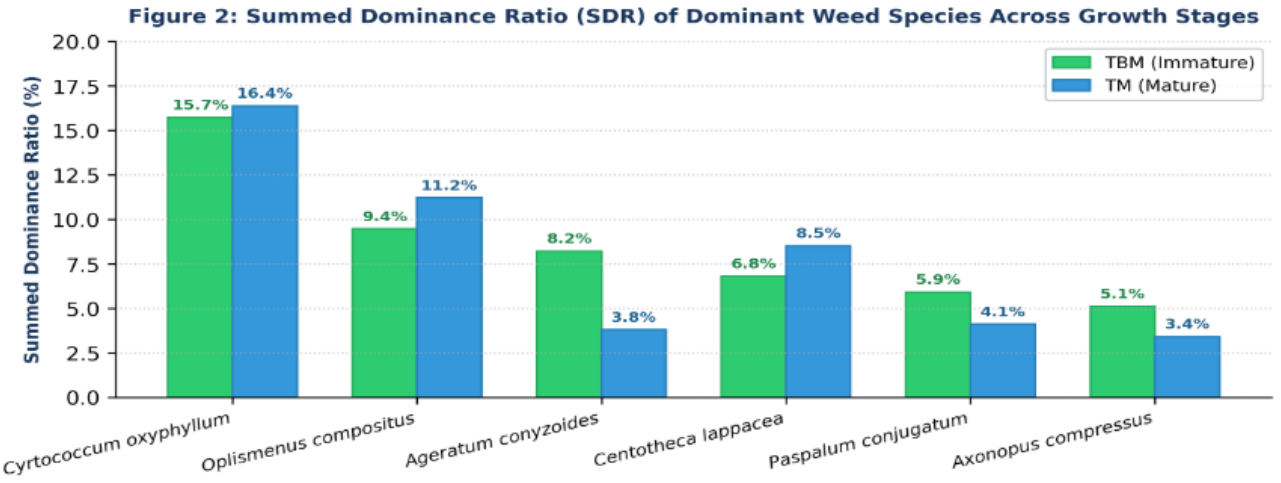


Figure 2. Summed Dominance Ratio (SDR %) of dominant weed species comparing immature (TBM, open canopy) versus mature (TM, closedcanopy) clove plantation stands in Hila Village.

5.2 Ecological Dominance of Cyrtococcum oxyphyllum

Quantitative evaluation established that Cyrtococcum oxyphyllum (Steud.) Stapf—a perennial trailing grass in the Poaceae family—is the single paramount dominant weed species across both growth phases of clove plantations in Hila Village. It recorded an SDR of 15.70% in TBM and rose to 16.36% in TM plantations (Table 1, Figure 2).

The exceptional ecological success of C. oxyphyllum in both unshaded and heavily shaded environments stems from its remarkable physiological plasticity and stoloniferous expansion strategy.

In TBM stands, it forms dense decumbent mats that outcompete erect broadleaf seedlings for surface soil nitrogen and moisture. In TM stands, where photosynthetic photon flux density (PPFD) drops significantly, C. oxyphyllum maintains efficient carbon assimilation through low light compensation points and rapid nodal rooting along trailing culms. This allows it to monopolize understory space where shade-intolerant species perish (Holm et al., 1977; Riry & Tanasale, 2019).

5.3 Community Similarity and Environmental Filtering

Calculation of Sorensen's Coefficient of Community yielded a value of CC = 60.55%. In vegetation ecology, a CC value below 65–70% signifies substantial floristic dissimilarity between two plant communities. The 39.45% divergence in community composition between TBM and TM stands underscores the powerful environmental filtering exerted by tree canopy development. While 15 species were shared between both stages, heliophilic broadleaves like A. conyzoides dropped from 8.20% SDR in TBM to 3.80% in TM, whereas shade-tolerant grasses like Oplismenus compositus increased from 9.45% in TBM to 11.20% in TM.

5.4 Integrated Weed Management (IWM) Implications

The empirical findings provide a solid ecological foundation for transitioning from uniform weed clearing to stage-specific

IWM in Maluku clove production:

Stage TBM Strategy: Priority must be given to suppressing light-responsive broadleaves and aggressive stoloniferous grasses. Establishing leguminous cover crops (LCC) such as Calopogonium mucunoides or Mucuna bracteata between young clove rows can effectively shade out weed seeds while suppressing C. oxyphyllum establishment and fixing atmospheric nitrogen.

Stage TM Strategy: Management must target sciophilous perennial grass mats. Mechanical slash-and-mulch combined with spot application of systemic herbicides (e.g., glyphosate at targeted thresholds) should replace broadcast spraying to prevent stolon fragmentation and soil exposure.

6. Conclusion

This study provides crucial ecological insights into weed community dynamics within smallholder clove plantations in Hila Village, Central Maluku Regency. Immature plantations (TBM) harbor higher species richness (28 species) due to open canopy conditions, whereas mature plantations (TM) support a specialized shade-tolerant flora (23 species). Across both developmental stages, Cyrtococcum oxyphyllum emerges as the undisputed dominant weed, achieving SDR values of

15.70% (TBM) and 16.36% (TM). The community similarity index of CC = 60.55% confirms significant floristic shifts driven by canopy light interception. Adopting stage-specific Integrated Weed Management (IWM)—focusing on cover cropping in TBM and targeted perennial grass control in TM—will optimize resource allocation, protect soil health, and enhance long-term clove yield sustainability in Maluku spice agroforestry.

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Multi-Sector Participatory Action for Revitalisation of the Island Cluster Healthcare System (ICHS) in Buru Regency, Maluku, Indonesia.

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Abstract

Maluku's extreme geography (92.4% marine territory, 1,412 islands) creates severe structural barriers to healthcare delivery, mirroring Small Island Developing States (SIDS). In Buru Regency (pop. 144,124 served by 1 hospital and 13 Puskesmas), continental- and urban-biased policies exacerbate maternal mortality (MMR 82/100,000) and infant mortality (IMR 266/1,000). To bridge the gap between the conceptual strength of the Island Cluster Healthcare System (ICHS) and its implementation, a Participatory Action Research (PAR) workshop was convened in November 2025 with 34 key institutional stakeholders across 5 thematic desks. The resulting multisectoral roadmap redefines transport and energy infrastructure as direct clinical necessities, establishes local legal mandates (PERBUP), transitions facilities to BLUD financial autonomy, and institutes an Archipelago Academic Health Hub.

Keywords: Archipelago Academic Health Hub, Archipelagic health governance, Island Cluster Health System, Participatory Action Research, Small Island development

1. Introduction & Background

Maluku Province embodies the "tyranny of distance" inherent in archipelagic governance. With 92.4% marine territory across 1,412 islands[1], geographical fragmentation severely impedes access to universal health coverage (SDG 3.8)[2, 3]. To mitigate these challenges, the Maluku Provincial Government initiated the Island Cluster Healthcare System (ICHS)[4], establishing regional referral hubs to streamline medical logistics and workforce placement. However, operational success still depends on maritime transport and telecommunications—critical bottlenecks in eastern Indonesia (Noya 2026, *unpublish*). Maternal deaths rose from 62 in 2022 to 77 in 2023.[5] In Buru Regency, serving 144,124 residents with only one regional hospital (RSUD) and 13 Puskesmas [6, 7], health disparities reflect a persistent continental bias in national regulations [8, 9]. Prior qualitative research established that patient-side barriers (1st delay) and referral/facility bottlenecks (2nd and 3rd delays) are driven by broader macro-level system failures rather than facility-level incompetence alone(Noya 2026, *unpublish*). National health policies often fail to account for the high-cost logistics of maritime governance, leaving peripheral island populations vulnerable[9]. This study addresses these systemic failures by shifting the analytical focus from problem identification to co-developing actionable, multisectoral policy solutions. Primary Objective: Grounded in the Health in All Policies (HiAP) framework[10] and the Social Accountability Partnership Pentagram[11], this study aims to formulate collective, locally informed, and measurable strategic actions across five interconnected domains: Regulation, Financing, Human Resources, Access, and Infrastructure. It offers a localised pathway to achieve United Nations SDGs 3 (Good Health), 10 (Reduced Inequalities), and 17 (Partnership).

2. Methods & Stakeholder Engagement

Study Design & Setting: As the second phase of a multi-stage research program (Noya 2026*, unpublish*), a Participatory Action Research (PAR)[12] multisectoral workshop incorporating Focus Group Discussions (FGDs) was conducted in Namlea, Buru Regency, on 14 November 2025.

Participants: The study convened 34 strategic supply-side stakeholders and institutional decision-makers. Representation spanned the Regional House of Representatives (DPRD), Regional Development Planning Agency (BAPPEDA), Health Office, Finance Office, Public Works (PU), BPJS Health, State Electricity Company (PLN), Telkom, and Puskesmas heads.

Data Collection & Analysis: Structured discussions were organised across five thematic round tables (desks):

- Desk 1: Regulation & Policy Mandates
- Desk 2: Budgeting & Financing Mechanisms
- Desk 3: Health Human Resources & Retention
- Desk 4: Access
- Desk 5: Regional Infrastructure

Qualitative data were analysed using thematic analysis, mapping sector-specific constraints, crosscutting dependencies, and binding operational interventions.

3. Key Results & Multisectoral Action Plan

Findings demonstrate that while the ICHS conceptual model is sound, cross-sectoral execution barriers stall outcomes. Key problems and time-bound strategic interventions across the five focus areas are summarised below:

Desk / Focus	Key Systemic Problems Identified	Strategic Solutions & Action Plan	Indicative Timeline
Desk 1: Regulation and Policy	Absence of binding local regulations for ICHS; weak enforcement of health worker rotations and service commitments.	Draft Regent Regulation (PERBUP ICHS) & SOPs for emergency referrals; establish mandatory service terms with reward/punishment systems.	Nov 2025 (Draft) 2026 (Impl.)
Desk 2: Budgeting and Financing	Population-based budgeting ignores high island logistics; BPJS gaps in inter-island sea referrals to Ambon.	Upgrade RSUD & Puskesmas to Regional Public Service Agency (BLUD) status; adopt geography/needs-based budgeting; advocate BPJS referral adjustments.	2025 – 2026
Desk 3: Human Resources	Severe shortage of specialists (OBGYN, Internal Med); failure of scholarship doctors to return; cultural barriers.	Enforce strict scholarship return decrees; establish Archipelago Academic Health Hub (AAHH) "rural pipeline"; adjust regional incentives and housing.	2025 – 2026
Desk 4: Access to Health Services	Limited emergency transport; intermittent electricity (2–3 hrs/night) and telecom outages disrupting telemedicine.	Procure Solar Power Plants (PLTS) for remote clinics; upgrade Sub-Health Centres (Pustu) to PHCs; provide standardised land/sea ambulances.	Q1 – Q2 2026
Desk 5: Infrastructure	Severely damaged provincial roads (Mako-Kayeli-Ilath-Batabual) causing 6-hour referral delays; high construction costs.	Accelerate road construction via INPRES No. 2/2025; expand ferry fleets (Batabual); build semi-permanent health staff housing.	2025 – 2029

4. Discussion & Policy Implications

Legal Formalisation & Fiscal Agility: Passing a local Regent Regulation (PERBUP ICHS) converts ICHS from an informal guideline into a binding 5-year administrative mandate (2026–2030). Transitioning

facilities to BLUD status provides the financial flexibility necessary for immediate boat maintenance and emergency referral fuel costs.

Bridging the Execution Gap: The study highlights a classic health system implementation gap. Health outcomes in archipelagic settings are heavily determined by Social Determinants of Health (SDH)—energy, roads, and transport—which fall outside the administrative control of the Health Office. Without binding intersectoral mechanisms (Intersectoral Action for Health - IAH), non-health sectors operate without synchronised health priorities.

Infrastructure as a Clinical Intervention: Crucially, this study redefines civil infrastructure as a direct clinical necessity. Broken roads (e.g., Mako-Kayeli-Ilath-Batabual route) and power outages directly drive the "Second Delay" (reaching care). Telemedicine is ineffective without a baseline of 24-hour electricity and telecommunications; transitioning to Solar Power (PLTS) is a prerequisite for emergency obstetric care.

The "Rural Pipeline" Model: To resolve chronic specialist shortages, the proposed Archipelago Academic Health Hub (AAHH)[13] merges medical education with regional health systems, training "island doctors" in local environmental contexts to foster long-term retention and cultural competence[14].

Strengths & Limitations: The PAR methodology ensures high ecological validity by directly involving decision-makers. Limitations include the single-day workshop scope and the need for longitudinal tracking of PERBUP implementation on MMR/IMR.

5. Conclusion & Strategic Next Steps

Revitalising the Island Cluster Healthcare System in Buru Regency requires moving beyond conceptual models to binding multisectoral execution. Legal formalisation via PERBUP ICHS, financial autonomy through BLUD, and reclassifying energy and roads as clinical interventions constitute the essential pathway. Integrating these actions into the 2026–2030 budget cycles ensures healthcare access becomes a right of citizenship rather than a privilege of proximity.

Acknowledgements: We thank SKALA Maluku Office, BAPPEDA Maluku Province, Buru District Government, Universitas Pattimura, and the Australia-Indonesia Institute (AII) for supporting and funding this research.

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Physicochemical Characteristics of "bakasang", a Traditional Fermented Fish Product from Banda Islands, Indonesia

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Abstract

"Bakasang" is a traditional fermented product produced through the activity of fermentative microbes, primarily lactic acid bacteria. In Maluku, this product is predominantly produced in the Banda Islands. The physicochemical characteristics of "bakasang" are influenced by raw material composition, the type of salt used, and fermentation duration. This study aimed to investigate the physicochemical properties of "bakasang" prepared from skipjack tuna (*Katsuwonus pelamis*) using four different production treatments: fish flesh with commercial salt (A1), fish flesh with coarse salt (A2), fish flesh and viscera with commercial salt (A3), and fish flesh and viscera with coarse salt (A4). The parameters analyzed included moisture content, protein content, pH, total titratable acidity (TTA), total volatile basic nitrogen (TVB-N), and salt content. The results showed that moisture content ranged from 58.75% to 66.10%, whereas protein content ranged from 19.33% to 34.21%. The pH values varied from 5.57 to 6.33, indicating shifts in acid-base characteristics across formulations during fermentation. TTA values ranged from 0.022 to 0.043 and tended to increase until the fourth week, with the highest value recorded in the formulation comprising fish flesh, viscera, and commercial salt. TVB-N values ranged from 22 mgN/100g to 102 mgN/100g, with the highest final value observed in the fish-flesh formulation prepared using commercial salt, whereas the corresponding formulation prepared with coarse salt exhibited a lower final value. Salt content ranged from 9.52% to 19.85%, and formulations containing viscera consistently exhibited higher salt concentrations compared to formulations consisting solely of fish flesh. Overall, the findings demonstrate that the physicochemical characteristics of "bakasang" vary depending on the formulation and fermentation duration. The inclusion of viscera was associated with higher final total titratable acidity (TTA) and salt content, while total volatile bases nitrogen (TVB-N) development showed distinct variations among treatments utilizing different salt types. These findings underscore the critical importance of raw material composition and salt selection in the production process of "bakasang"

Keywords: "bakasang"; skipjack tuna; fermentation; physicochemical properties; total volatile bases nitrogen; total titratable acidity; salt content.

Small Islands Environmental Law Education: Strategies to Rediscover the Future Value of Island Regions.

Dyah R.A. Daties

Abstract

Introduction: National regulations concerning the environmental law of small islands—such as Law No. 32 of 2009 on Environmental Protection and Management and Law No. 27 of 2007 on the Management of Coastal Areas and Small Islands, to various technical regulations such as Government Regulations (PP) and Ministerial Regulations—have established a robust normative foundation for ensuring the protection of small-island ecosystems while supporting sustainable development. However, theoretical reflection reveals a gap between legal norms and their practical implementation. A limited understanding of UNCLOS 1982, environmental law, and the legal status of small islands has resulted in a lack of community participation—even though the community is a key actor of the sustainability of small islands.

Purposes of the Research: This paper explains the effectiveness of the implementation of regulations, as well as describes the main materials for environmental law education of small islands.

Methode of research: The research method is qualitative, utilizing a library research approach, with data gathered from laws, government regulations, ministerial regulations, books, journals, and relevant scholarly literature. The analysis is conducted in a normative and descriptive manner, emphasizing the integration of legal principles, international law, national policies, and the participation of communities.

Empowering Coastal Fishermen: A Standalone Wind-Solar Micro-Hybrid System for Renewable Cold Chains

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In small, remote island communities such as Talaga Nipa Hamlet in West Seram, local fishermen face severe economic hurdles because the absence of a reliable electrical grid and high fossil fuel costs disrupt the fishery cold chain, causing catches to spoil rapidly before reaching mainland markets. To overcome this challenge, this study designed, integrated, and field-tested a standalone 1 kW off-grid wind-solar micro-hybrid system engineered specifically to power productive cooling loads consisting of a mini cold storage unit and an ice maker with a 200–300 kg capacity. To guarantee 24-hour continuous refrigeration without fuel dependency, the system architecture combines five components optimized for harsh tropical marine conditions: a 700 Wp monocrystalline PV solar array that captures peak daytime solar radiation, a 300–400 W helical vertical-axis wind turbine (VAWT) with an ultra-low cut-in speed of 2.0–2.5 m/s for steady nighttime sea winds, a BMS-protected 24V 150 Ah LiFePO4 battery providing long cycle life and thermal safety, a pure sine wave inverter equipped with soft-start functionality to suppress compressor inrush current, and a hybrid MPPT controller that optimizes simultaneous energy harvesting from both solar and wind power. Field testing in Talaga Nipa Hamlet demonstrated that combining daytime solar and nighttime wind energy generated 3,715 Wh/day—yielding a clean energy surplus of 215 Wh/day above the 3,500 Wh/day cooling demand—while maintaining a stable 24-hour freezing temperature of -18°C. This zero-carbon cold chain reduced tuna post-harvest spoilage loss to 0% and increased fishermen's selling prices and income by 25–35%. Ultimately, this research delivers a proven strategic best-practice blueprint for decentralized energy transitions in remote, outermost, and underdeveloped (3T) island regions, replacing fossil fuel reliance with self-sustaining micro-hybrids to strengthen maritime food sovereignty, empower coastal communities, and accelerate regional climate resilience.

Keywords: 3T energy transition, fishermen post-harvest resilience, helical wind turbine, micro-hybrid system, solar panel array, standalone cold chain

Insect Biodiversity in Traditional Agroforestry: Exploring the Ecological Value of *Dusung* for Sustainable Small-Island Landscapes in Maluku, Indonesia

J. A. Leatemia

Abstract

Traditional agroforestry systems contribute to the agricultural landscapes of small islands, yet information on their associated insect biodiversity remains limited. In Maluku, eastern Indonesia, *dusung* is a locally developed agroforestry system that integrates perennial crops and other vegetation within a traditional land-use system. This study assessed insect diversity and community structure in two *dusung* types—nutmeg-based (*dusung pala*) and fruit-based (*dusung buah*)—on Ambon and Saparua Islands. Insects were sampled using complementary trapping methods across 80 plots in 16 villages. The collected specimens were identified and classified by taxonomic group and ecological functional group. In total, 6,014 insect individuals were recorded. Nutmeg-based *dusung* contained 2,491 individuals representing nine orders, 27 families, 40 genera, and 42 species, whereas fruit-based *dusung* contained 3,523 individuals representing seven orders, 21 families, 29 genera, and 31 species. Despite its lower abundance, nutmeg-based *dusung* exhibited higher Shannon diversity ($H' = 2.45$) and evenness ($E = 0.63$), together with lower Simpson dominance ($D = 0.14$), than fruit-based *dusung* ($H' = 1.31$, $E = 0.38$, and $D = 0.51$). Herbivores dominated both systems, accounting for 67.84% of individuals in nutmeg-based *dusung* and 84.28% in fruit-based *dusung*. These contrasting patterns demonstrate that traditional *dusung* systems support distinct insect assemblages, with differences in taxonomic richness, abundance, and community structure. The findings provide baseline information for insect biodiversity assessment and highlight the ecological relevance of traditional agroforestry in discussions of sustainable land management on small islands.

Keywords: agroforestry; insect diversity; *dusung*; functional groups; small islands; Maluku

Socio-Ecological Resilience, Climate Adaptation, and Sustainable Agroforestry in the Maluku Islands, Indonesia

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Abstract

This study examines the sustainability of island landscapes in the Maluku archipelago through agroforestry-based livelihoods in the Wai Nia Watershed, Nusalaut Island, Central Maluku. Using secondary baseline data from 50 households in Abubu and Nalahia villages, together with climate records for 2004–2023, the study applies a descriptive-analytical approach within a socio-ecological resilience framework. Climate data show substantial interannual variability in temperature and rainfall, though long-term trends require further statistical testing. Agroforestry systems differ between villages, and households reported productivity declines of 20–80%, with most classified as very low-income. Gender relations and youth outmigration further shape sustainability. The study proposes five strategic directions: climate-resilient agroforestry, value-added processing, gender-responsive governance, climate information services, and institutional collaboration, positioning Maluku as a strategic socio-ecological asset.

Keywords: Resilience, Agroforestry, Adaptation, Maluku, Livelihood

Archipelagic regions are strategic socio-ecological spaces whose significance goes beyond geographic isolation and limited land. Islands support distinctive biodiversity, regulate coastal and marine processes, maintain cultural landscapes, and sustain livelihoods tied to local ecosystems. Yet island communities face interconnected pressures: climate variability, environmental degradation, limited infrastructure, dependence on primary commodities, demographic change, and unequal access to productive resources. In the Maluku Islands of eastern Indonesia, dispersed settlements, reliance on natural-resource livelihoods, and the historical role of spice-based agroforestry create both development opportunities and structural vulnerabilities.

Understanding the future value of Maluku therefore requires an integrated perspective that treats ecological integrity, livelihood security, cultural identity, and institutional capacity as interdependent foundations of island sustainability. This view follows socio-ecological resilience theory, which stresses the capacity of coupled human–environment systems to absorb disturbance, reorganize, and retain essential functions (Adger, 2000; Folke, 2006; Walker et al., 2004; Ostrom, 2009; Biggs et al., 2012).

This case study focuses on agroforestry-based livelihoods in the Wai Nia Watershed, Nusalaut Island, Central Maluku Regency. It uses secondary data from an initial baseline assessment in Abubu and Nalahia villages: 50 household respondents (30 in Abubu, 20 in Nalahia), climate records for 2004–2023, land-use information, observations of agroforestry plots, and community perspectives on environmental change. A descriptive-analytical approach examines relationships among climate variability, landscape characteristics, agroforestry practices, household vulnerability, gender relations, and adaptation pathways, within a framework that combines socio-ecological systems, climate vulnerability, livelihood diversification, ecosystem services, and gender-responsive adaptation (Smit & Wandel, 2006; Engle, 2011; Cumming et al., 2013; Thomas et al., 2020; Beck et al., 2023).

The baseline data show substantial interannual variability. Annual air temperature ranged from 21.24°C (2012) to 28.80°C (2013) around a 2004–2023 mean of 25.77°C (Figure 1), while annual precipitation ranged from 1,291.30 mm (2015) to 4,733 mm (2008), with a mean of 2,822.86 mm/year (Figure 2). Extreme values alone are not evidence of statistically significant long-term trends or of direct attribution to climate change; data-quality checks and trend analysis are still needed. The distinction

matters because island vulnerability is shaped not only by climate hazards but also by exposure, sensitivity, adaptive capacity, and the social and institutional conditions that govern response (Hinkel, 2011; Barnett & Adger, 2003).



Figure 1. Annual air temperature in Central Maluku, 2004–2023 (°C)



Figure 2. Annual rainfall in Central Maluku, 2004–2023 (mm/year)

The two villages differ clearly. In Nalahia, about 75% of identified land use is home gardens, whereas Abubu has a larger share of dryland (about 48%) and locally classified forest (about 38%). Mixed, randomly distributed cropping occurs in about 71% of agroforestry plots in Nalahia and 41% in Abubu (Table 1). Agroforestry in Nusalaut is therefore not a uniform system but a landscape practice shaped by ecological conditions, settlement patterns, land-use history, and household management. Dominant commodities are nutmeg (*Myristica fragrans*), cloves (*Syzygium aromaticum*), durian, banana, cassava, and sweet potato; combining annual and seasonal crops can diversify household income and maintain ecological functions. Diverse agroforestry can support biodiversity, resource-use efficiency, soil and water conservation, and smallholder resilience, although outcomes depend on species composition, management, and local socioeconomic conditions (Jose, 2009; Mbow et al., 2014; Lin, 2011; Duffy et al., 2021).

Table 1. Agroforestry systems in Nalahia and Abubu villages

Variable	Nalahia (N)	Nalahia (%)	Abubu (N)	Abubu (%)
Composition of commodities				
(A) 1 forestry type + 1 agriculture type	7	20	2	4
(B) 1 forestry type + several agriculture types	0	0	11	21
(C) Several forestry types + 1 agriculture type	27	77	0	0
(D) Several forestry types + several agriculture types	1	3	39	75
Total	**35**	**100**	**53**	**100**
Pattern: mixed cropping / random mixture	25	71	22	41
Pattern: alternate rows	9	26	11	21

Source: analyzed from survey data, 2023.

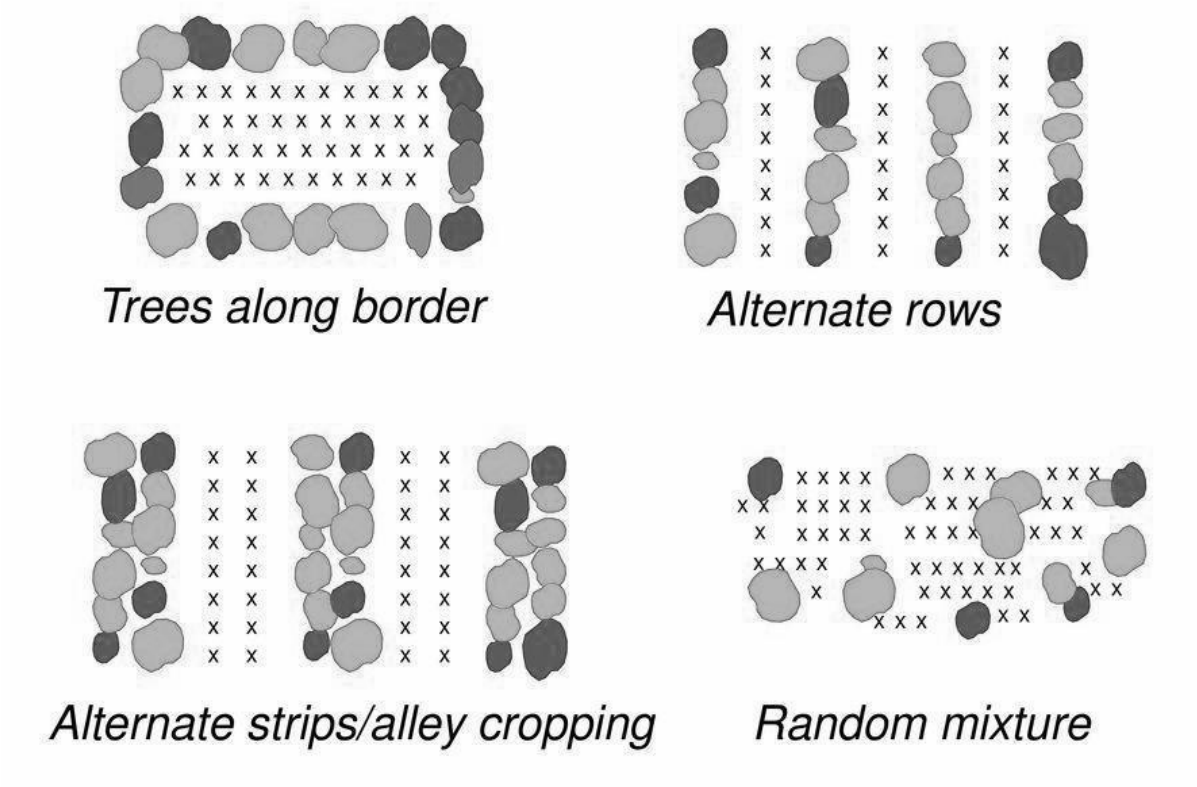


Figure 3. Agroforestry systems

Respondents reported changing rainfall patterns, rising temperatures, soil drought, flower and fruit drop, pest and disease pressure, and crop failure. Reported productivity declines were 20–40% in Nalahia and 60–80% in Abubu. These figures reflect perceptions rather than measured yield losses, but they show how households interpret environmental change; differences between villages likely reflect land use, crop composition, exposure, and household capacity to cope. Adaptation through agroforestry and diversification is context-dependent and can be limited by access to finance, technology, markets, extension services, and secure resource rights (Lasco et al., 2014; Bravo-Peña & Yoder, 2024; Dittmer et al., 2023; Thomas et al., 2020).

Under the baseline assessment's income thresholds, 17 of 20 respondents in Nalahia (85%) and 28 of 30 in Abubu (about 93%) were classified as very low-income; these are not current official poverty statistics for Maluku. Dependence on a few commodities increases exposure to production shocks and price fluctuations where alternative employment, financial services, and market access are limited, so livelihood diversification is central to island resilience (Barrett et al., 2001; Ellis, 2000; Adger, 2000).

The local social structure is patrilineal, with men generally holding greater influence over land ownership and land-use decisions. Women nonetheless contribute substantially to post-harvest processing, packaging, marketing, and household financial management. Younger people increasingly seek education and work outside the villages, which may reduce household labor and the transmission of agricultural knowledge. Agroforestry sustainability therefore cannot be judged by crop productivity or land cover alone; it also requires attention to decision-making authority, access to productive resources, recognition of women's economic roles, and youth participation. Gender-responsive adaptation is essential because women and men experience climate risk differently (Haque et al., 2023; Djoudi et al., 2016; Carr & Thompson, 2014; Jost et al., 2016).

Traditional agroforestry landscapes, including *dusung* systems, are multifunctional socio-ecological assets that support biodiversity conservation, soil protection, carbon storage, food provision, cultural continuity, and local economies. Studies in Indonesia link agroforestry to food security and livelihood

diversification, and work in Maluku highlights the economic and institutional importance of *dusung* and nutmeg-based systems (Duffy et al., 2021; Hahury et al., 2020; Girsang et al., 2024). Their value is both material and non-material, spanning ecosystem services, cultural identity, traditional knowledge, and social relationships, and land-use decisions involve trade-offs between economic development and ecological sustainability (Costanza et al., 1997; Díaz et al., 2018).

Five interrelated directions are proposed to strengthen the sustainability of the Maluku Islands region:

1. Climate-resilient agroforestry that combines perennial crops, seasonal food crops, and multipurpose trees suited to local conditions.
2. Value addition through processing and marketing of nutmeg, cloves, bananas, chilies, and other local commodities.
3. Gender-responsive and intergenerational governance: stronger women's participation in decision-making, better access to productive resources, and youth engagement in agricultural innovation and digital marketing.
4. Ecological monitoring and climate information services to support evidence-based land and resource management.
5. Institutional collaboration among village governments, customary institutions, universities, local businesses, and local governments.

These directions reflect the importance of adaptive governance, collective action, institutional learning, and cross-scale coordination in complex social-ecological systems (Ostrom, 2009; Folke, 2006; Berkes & Ross, 2013; Biggs et al., 2012).

This study frames the Maluku archipelago as a strategic socio-ecological asset rather than a peripheral region defined by isolation. Its future sustainability depends on linking ecological integrity with inclusive economic transformation, cultural continuity, and community resilience, and agroforestry is a critical entry point for integrating climate adaptation, biodiversity conservation, livelihood diversification, and local economic development. Agroforestry alone cannot resolve structural vulnerabilities without supportive institutions, infrastructure, market access, appropriate technology, and equitable resource governance. The Nusalaut case shows the value of locally rooted strategies and the need for comparative research across island ecosystems in Maluku.

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