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Integrating Subak Local Wisdom to Enhance Sustainable Agricultural Entrepreneurship and Economic Development in Tolai Village

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Abstract:

This study explores the integration of local wisdom, specifically the Subak system, into sustainable agricultural entrepreneurship in Tolai Village, Torue District, Parigi Moutong Regency. Subak, a traditional Balinese irrigation system, incorporates the principles of Tri Hita Karana, which emphasizes harmony between humans, nature, and spirituality. The research examines how Subak practices, combined with modern agricultural techniques, promote ecological sustainability, enhance agricultural productivity, and strengthen community cohesion. The study also discusses the challenges faced by Subak, such as irrigation infrastructure issues, climate change, and pest management, and highlights adaptive strategies implemented by local farmers. Furthermore, the study underscores the importance of knowledge transfer to younger generations to ensure the continuity of Subak and its practices. The findings suggest that the integration of local wisdom into agricultural entrepreneurship contributes to the preservation of cultural heritage, supports food security, and fosters socio-economic resilience in rural communities.

Keywords: *Subak system, Local wisdom, Sustainable agriculture, Tri Hita Karana, Knowledge transfer*

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1. Introduction

The integration of local wisdom into agricultural entrepreneurship plays a pivotal role in fostering resilience and sustainability, particularly within rural communities. Local wisdom encompasses traditional knowledge and practices that have been passed down through generations. These practices offer valuable insights into sustainable land management, crop rotation, and biodiversity conservation, all of which contribute to improving agricultural productivity while minimizing ecological footprints. Research suggests that utilizing local wisdom in agriculture leads to contextually appropriate solutions that enhance the success rates of local farmers and agripreneurs (Guampe & Taaha, 2022; Komolafe et al., 2022; Mupfasoni et al., 2018).

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In rural areas, the synergy between local knowledge and modern agribusiness strategies is crucial for advancing agricultural entrepreneurship. Educational programs that incorporate local wisdom not only cultivate entrepreneurial skills but also foster innovation by adapting sustainable practices to the specific ecological and social contexts of each region. These programs equip farmers and aspiring agripreneurs with the necessary competencies to blend traditional farming methods with modern innovations, promoting environmentally friendly and economically viable agricultural ventures (Gadanakis, 2024; Guampe et al., 2022; Kurtsal et al., 2024; Pliakoura et al., 2020).

Furthermore, local wisdom plays an essential role in community-based resource management, which is fundamental for sustainable agricultural entrepreneurship. By involving local communities in decision-making processes, strategies are better aligned with the socio-cultural dynamics of the area, which enhances the acceptance and sustainability of agricultural practices. Studies show that community engagement, grounded in local knowledge, leads to improved resource stewardship and significantly boosts economic outcomes by enhancing agricultural productivity and developing local markets (Bignotti et al., 2021; Gadanakis, 2024; Sargani et al., 2020).

Moreover, integrating local wisdom into agricultural entrepreneurship contributes to the preservation of cultural heritage and improves food security. This is achieved by promoting the cultivation of indigenous crops and the use of traditional farming methods, which increase crop diversity and resilience against climate change. Such practices enable local farmers to better adapt to environmental uncertainties (Abdullah et al., 2020; Ionescu et al., 2022; Pliakoura et al., 2020, 2023). Thus, sustainable agricultural entrepreneurship nurtured by local wisdom supports not only economic livelihoods but also strengthens community ties and ecological sustainability.

Lastly, collaboration between local farmers and educational institutions is crucial for bridging the gap between traditional knowledge and modern agricultural science. Programs designed to enhance farmers' entrepreneurial skills and foster innovation can play a key role in creating a knowledgeable workforce that values both local practices and innovations, ultimately advancing sustainable development in agricultural systems (Anusree & Swarupa, 2024; Guampe, 2021; Hasan et al., 2025; Iyer, 2021; Thephavanh et al., 2023).

The Subak system, a traditional Balinese irrigation method, exemplifies the rich local wisdom that underpins sustainable agricultural practices. Recognized by UNESCO as a World Heritage site, Subak integrates community ownership, ecological balance, and the Tri Hita Karana philosophy, which emphasizes harmony between humans, nature, and the divine. These principles are essential for maintaining the sustainability of agricultural practices. As a cooperative system of water management, Subak fosters efficient irrigation while promoting social cohesion among farmers. Research has shown that the system encourages the preservation of cultural heritage and biodiversity, even in the face of modern challenges such as land conversion for tourism and urbanization (Arsana et al., 2022; Sriartha & Kertih, 2020; Zen et al., 2024). As pressures from globalization threaten the Subak system, understanding and applying local wisdom in contemporary contexts is critical for its preservation (Prastyadewi et al., 2023; Suryawan et al., 2023).

Incorporating Subak's principles into educational curricula not only promotes environmental education but also ensures the sustainability of this vital agricultural system by instilling values of communal responsibility in younger generations. The integration of traditional knowledge with modern educational methodologies helps foster a sense of identity and purpose, ensuring the long-term viability of Subak and its associated cultural practices (Saputra et al., 2024; Sriartha et al., 2017; Vitiara et al., 2024). Moreover, the economic potential of Subak has extended into community-based tourism, which provides economic benefits while promoting the conservation of this unique agricultural system (Arı et al., 2024; Prastyadewi et al., 2023; Wiranatha et al., 2024).

Therefore, integrating local wisdom into agricultural entrepreneurship, exemplified by the Subak system, is essential for balancing development and conservation efforts, securing food sovereignty, and enhancing the socio-economic resilience of rural communities.

2. Theoretical Background

Social ecology theory: Social ecology theory emphasizes the interconnectedness of social and ecological systems, where human societies exist in a continuous interaction with their environmental contexts. This dynamic relationship is crucial for understanding sustainability, resilience, and community well-being. A significant aspect of social ecology is the recognition of how socio-ecological systems (SES) operate as complex adaptive systems, influenced by social, political, and ecological processes over time. The adaptive cycle model elucidates the phases of collapse and recovery within SESs, highlighting the need for policies and interventions that foster resilience and adaptability to changes and disturbances (Abel et al., 2006; Adger, 2000).

An important principle within social ecology is the necessity of considering the socio-political realities of communities in ecological restoration and management for it to be effective. The integration of social needs, knowledge, and institutions is essential for successful biodiversity conservation strategies, especially those aimed at preventing the emergence of diseases in human populations (Schneider et al., 2021). Furthermore, studies indicate that urban environments can significantly benefit from green space planning, as these spaces enhance both ecological functionality and community health outcomes (Bentley, 2013; Teimouri et al., 2023). The role of urban green spaces illustrates the necessity of employing a holistic approach to urban planning that incorporates both environmental and social dimensions, facilitating improvements in public health and social equity (Heymans et al., 2019).

Moreover, research into urban ecosystems has revealed the importance of resilience in both ecological and social contexts. Communities that rely heavily on their local ecosystems for resources must develop capacities to withstand ecological changes, indicating a direct connection between social and ecological resilience (Adger, 2000; Çiftçioğlu, 2019). By embedding principles of resilience thinking into urban design

and policy, cities can evolve into more sustainable entities that support both human well-being and ecological integrity, particularly under the growing pressures of climate change and urbanization (Lounsbury & Mitchell, 2009; Pont et al., 2022). In this regard, the concept of social-ecological urbanism (SEU) merges urban planning with ecological principles to cultivate urban spaces that are not only livable but also responsive to environmental changes, thereby promoting long-lasting social and ecological benefits (Colding et al., 2022).

Cultural Ecology Theory: Cultural Ecology Theory explores the complex interdependence between human culture and the environment, recognizing that both cultural practices and ecological systems are dynamically interactive. It posits that cultural forms and social structures are shaped by the natural environment, while in turn, they also influence and adapt to ecological changes. This ongoing exchange highlights the evolving relationship between culture and ecology, rather than a static one. Recent studies underscore the applicability of cultural ecology across various domains, revealing how cultural practices evolve in response to ecological conditions and historical contexts. For example, research on Shiwan pottery techniques in China shows how cultural practices adapt to the environment (Zhou et al., 2023), while studies on the digital application of cultural heritage demonstrate the complex interplay between culture, ecology, and technology (Jing et al., 2021).

Further studies have emphasized the importance of integrating social-ecological systems to inform sustainable resource management. Lee, (2021) asserts that successful conservation requires understanding how human-environment interactions shape ecological management. Similarly, Lyon and Parkins' framework of resilience highlights the adaptability of cultural and ecological systems in navigating economic and environmental transitions, underscoring the role of cultural attributes in fostering resilience amid ecological challenges. This perspective encourages a reassessment of how communities can mobilize cultural practices to enhance sustainability and respond to environmental changes effectively.

Cultural ecology also intersects with other ecological theories, such as human ecology and community resilience. Bubolz and Sontag's human ecology theory explores the interdependency of humans as biological and social beings within their environments, positioning cultural practices within broader ecological contexts. Gunderson, (2010) links community resilience to ecological theory, showing how cultural responses to ecological disturbances are crucial for societal recovery. As cultural ecology continues to evolve, ongoing research into the interaction between socio-cultural practices and ecological factors is essential. Ingalls & Stedman, (2017) propose a dialectical approach to studying how human identity is shaped by social and ecological interactions, further illustrating the value of cultural ecology in understanding the resilience and adaptability of human societies in response to environmental change.

Local Knowledge Theory: Local Knowledge Theory explores how localized knowledge systems develop, their significance within communities, and their

applications in areas like environmental policy, indigenous practices, and development. Local knowledge often emerges in response to the limitations of conventional scientific knowledge, especially in environmental management and conservation. It represents a diverse range of knowledge forms that interact with specific environments and can challenge traditional scientific paradigms (Congretel & Pinton, 2020). This knowledge is deeply tied to the socio-cultural context of a community and reflects evolving practices and beliefs that shape their survival strategies and identity (Lah et al., 2015; Sunanlikanon, 2021).

The connection between local knowledge and environmental governance is vital, particularly in sustainable ecosystem management. Indigenous and local knowledge systems, developed through long-term experimentation, enhance our understanding of biodiversity and its role in human well-being. Integrating local knowledge with scientific methods can improve environmental stewardship and policy effectiveness while promoting social equity and enhancing procedural democracy (Corburn, 2003; Tengö et al., 2014). This integration also plays a significant role in development practices, as recognizing local knowledge allows for better community engagement and more effective policy outcomes (Nugroho et al., 2018; Smith, 2011).

In the context of disaster risk management, local knowledge is crucial for developing effective hazard management and response strategies. It informs risk mitigation efforts and strengthens community resilience (Setten & Lein, 2019). Additionally, traditional knowledge, often overlooked by formal planning systems, is essential for sustainability and conservation efforts (Rantanen & Kahila, 2009). The modern integration of local knowledge with technology and social networks further enhances its relevance, enabling more dynamic and place-based solutions to community issues (Ludford et al., 2007; Park et al., 2014). Overall, these discussions highlight the critical importance of local knowledge across various fields.

Sustainable Development Theory: Sustainable Development Theory is a comprehensive framework that integrates social, economic, and environmental factors to address contemporary challenges. It advocates for a balanced approach that satisfies current needs without compromising the ability of future generations to meet their own. Rooted in economic principles, the theory emphasizes the importance of harmonizing resource utilization with environmental conservation. As the global economy faces issues like climate change and resource depletion, the application of ecological economics and sustainable development models becomes essential for managing resources in a way that also promotes social equity and environmental stewardship (Samofatova, 2017; Shi, 2024).

In addition to economic and ecological perspectives, the role of innovation has become crucial in advancing sustainability. New technologies and business models offer practical solutions to reduce ecological footprints and enhance social welfare. Organizational strategies focused on sustainability, particularly in supply chains, show how holistic approaches benefit both the environment and the economy (Pondel & Bludnik, 2018). Furthermore, the psychology of sustainability explores how

individual and collective behaviors influence sustainability efforts, highlighting the importance of understanding human motivations to encourage sustainable practices at both personal and societal levels (Fabio, 2017; Maree & Fabio, 2018).

3. Methodology

Research Location and Time

This study was conducted in Tolai Village, Torue District, Parigi Moutong Regency, selected for its relevance to the research on the integration of the Subak system into local agricultural practices. The research began on December 28, 2024, and will continue until its completion.

Research Design

A qualitative ethnographic research design was used to understand the Subak system and its impact on sustainable agriculture. Ethnography was chosen for its ability to capture the complexities of social structures, traditions, and practices within a community. Data were collected through participant observation, structured interviews, and secondary data analysis to ensure a comprehensive understanding of the topic (Creswell & Creswell, 2018).

Research Informants

The study involved 12 key informants, selected to provide a comprehensive range of insights into the Subak system in Tolai Village. These informants included two Heads of Subak (Pekaseh), who are responsible for overseeing the irrigation system and its collective management. Additionally, one Mangku (spiritual leader) was included, offering valuable perspectives on the spiritual and philosophical aspects of Subak. To further understand the agricultural practices, three Subak farmers and three non-Balinese farmers were selected, representing a diverse mix of participants involved in the system's implementation. Finally, two young village members were included to provide insights into the generational transfer of knowledge and the future sustainability of the Subak system. These informants were carefully chosen to ensure a well-rounded understanding of the Subak system, incorporating viewpoints from various stakeholders in the community.

Data Collection Techniques

Data for this study were collected through structured interviews with key informants, including the Heads of Subak, spiritual leaders, farmers, and young community members. These interviews provided in-depth insights into the practices, governance, and spiritual dimensions of Subak, as well as its role in promoting sustainable agricultural practices in Tolai Village. The structured format allowed for consistent data collection, ensuring that the views and experiences of each informant were thoroughly captured.

In addition to interviews, participant observation was employed as a data collection method. The researcher actively engaged in community agricultural activities and rituals, participating alongside local farmers to gain firsthand experience of the

practices surrounding the Subak system. This immersive approach allowed for a deeper understanding of how Subak functions in practice, revealing the daily interactions, cultural significance, and collective decision-making processes integral to its sustainability.

Data Management and Analysis

Data were managed and analyzed in a systematic manner to ensure reliability:

a. Data Editing: All collected data were reviewed for accuracy and clarity, ensuring consistency across interviews, field notes, and secondary sources.

b. Data Classification: Data were organized into thematic categories, such as water management, community involvement, and cultural practices, to identify key trends and patterns.

c. Data Analysis: The data were analyzed using the interactive model of Miles and Huberman (1992), which involves data reduction, presentation, and conclusion drawing. Key insights were derived regarding the role of the Subak system in sustainable agricultural practices and community cohesion.

4. Empirical Findings/Result

Respondent profile

Table 1. Respondent profile: Gender, age, education

No	Name	Gender	Age	Education
1	I Wayan Sukerta	Male	51	Junior High School
2	Gede Subagia	Male	46	Senior High School
3	I Komang Pujawan	Male	37	Bachelor's Degree
4	Alit Natarianto	Male	44	Bachelor's Degree
5	Alit	Male	53	Senior High School
6	I Nyoman Suarta	Male	55	Senior High School
7	Pak Yuni	Male	53	Senior High School
8	Apan Kelana	Male	48	Senior High School
9	Dwi Lestari	Famale	28	Bachelor's Degree
10	Jein Baturangka	Famale	35	Senior High School
11	Arya Ghiodana	Male	25	Bachelor's Degree
12	Deddy	Male	29	Bachelor's Degree

Table 1 presents the respondent profile in this study, which includes information on gender, age, and education. There are a total of 12 respondents, with the majority being male (10 respondents) and two female respondents. The age range of the respondents is between 25 and 55 years, with an average age of approximately 42 years. In terms of education, most respondents have a high school education (7 respondents), while 4 respondents hold a Bachelor's degree, and 1 respondent has completed junior high school. This profile reflects a diverse background in terms of

education and age, providing a broad range of perspectives in the context of integrating Subak local wisdom to support sustainable agricultural entrepreneurship in Tolai Village.

Data Classification

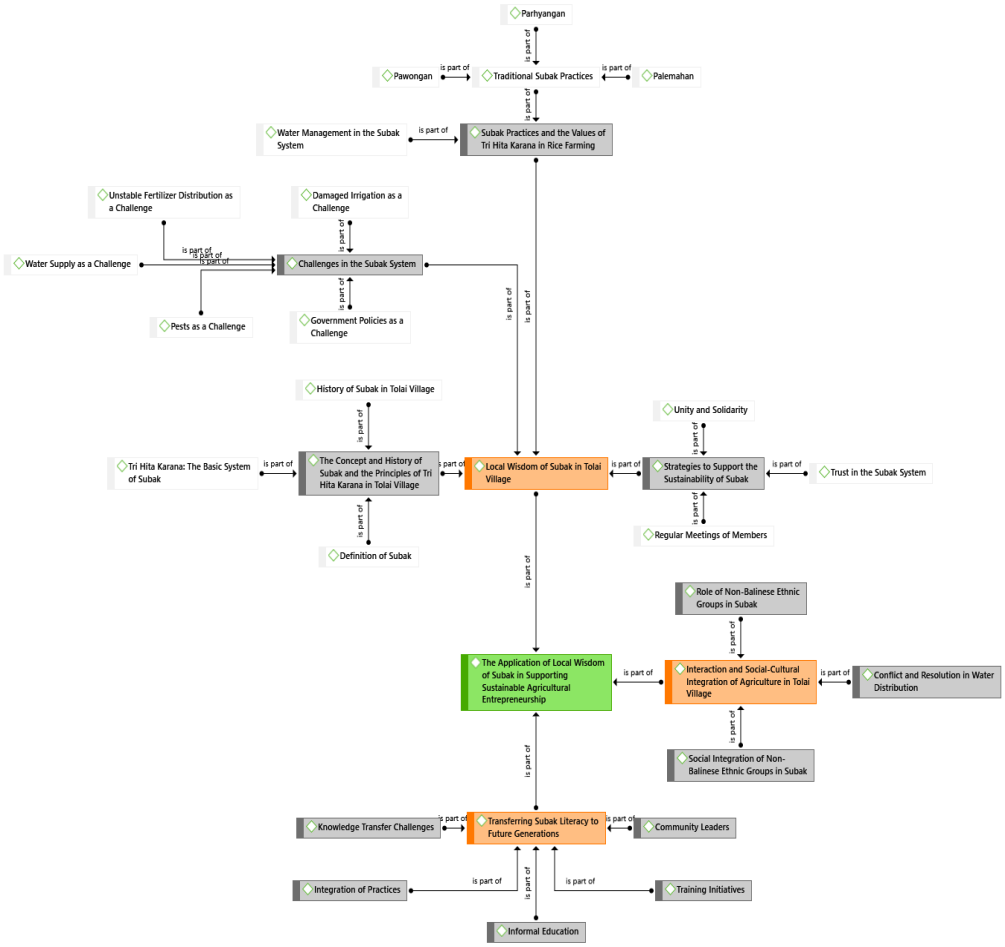

Figure 1. The Application of local wisdom of subak in supporting sustainable agricultural entrepreneurship

This Figure 1 illustrates the results of research on the application of Subak local wisdom to support sustainable agricultural entrepreneurship in Tolai Village. The focus of the study, depicted in green, is on the implementation of Subak, which forms the core of sustainable agricultural entrepreneurship in the village. The application of Subak local wisdom in Tolai Village is examined through various dimensions that are analyzed in depth. These dimensions, represented in orange, cover aspects related to social interaction, culture, and resource management that are essential for supporting sustainable entrepreneurship. One of the key dimensions is the application of Subak itself, which serves as the foundation for the sustainability of agriculture in the village.

In this regard, Subak plays a crucial role as a water and agricultural management system closely tied to the Tri Hita Karana values that emphasize harmony between humans, nature, and God.

Additionally, another dimension examined is the strategies employed by the community to ensure the long-term sustainability of Subak. These strategies involve efforts to maintain solidarity among community members and enhance trust in the Subak system. The study also explores how social interaction and socio-cultural integration in agriculture impact the sustainability of the Subak system in Tolai Village, as well as how the application of Subak local wisdom contributes to the development of sustainable agriculture-based entrepreneurship.

The indicators identified in the study, depicted in gray, represent specific elements that can be measured and observed in the context of the application of Subak in Tolai Village. The first indicator is the importance of regular meetings among community members to sustain the Subak system and ensure effective communication among them. Furthermore, the role of non-Balinese ethnic groups in Subak is another relevant indicator, reflecting how non-Balinese ethnic groups participate in the Subak system, contributing to diversity and social integration within it. Trust in the Subak system is also a significant indicator, reflecting the level of confidence members have in the reliability and sustainability of the system.

Challenges in water management are another indicator, showing how uneven water distribution and government policies affect the continuity of the Subak system. The transfer of Subak knowledge to future generations is a significant challenge, emphasizing the importance of passing on Subak literacy to the younger generation to ensure these values are continuously applied and preserved. Efforts in informal education to transfer this knowledge become an additional indicator, demonstrating the essential role of non-formal education in preserving Subak local wisdom for future generations. All of the dimensions and indicators identified in this study illustrate the complexity and challenges faced in applying Subak local wisdom as the foundation of sustainable agricultural entrepreneurship in Tolai Village.

5. Discussion

Implementation of Local Wisdom Subak in Tolai Village

Concept and History of Subak and the Tri Hita Karana Principle in Tolai Village

The Subak system, as implemented in Tolai Village, is a unique agricultural adaptation, stemming from the migration of Balinese transmigrants to the region in 1969. This introduction marked the shift from traditional shifting cultivation practices, such as *Mampeita Wula Ilangi*, to a more organized and collective irrigation-based agricultural system. The system reflects the fusion of Balinese agricultural wisdom with the indigenous practices of the Tolai people, creating a hybrid model that balances ecological sustainability, agricultural productivity, and social cohesion. As highlighted by Zen et al., (2024), the integration of indigenous knowledge with

modern practices fosters resilience and sustainability in agriculture, ensuring that farming practices can adapt to local environmental conditions.

At the heart of Subak in Tolai is the Tri Hita Karana principle, which emphasizes the balance between humans (pawongan), nature (palemahan), and spirituality (parhyangan). This philosophy is not only a framework for agricultural management but also a guiding principle for social organization and communal living. As discussed by Arsana et al., (2022), the Tri Hita Karana approach reinforces the importance of maintaining harmony between humans and their environment, a principle that is deeply ingrained in Subak's functioning.

Historically, the introduction of Subak transformed Tolai's agricultural landscape, shifting the region from rainfed subsistence farming to a more sustainable, irrigated rice cultivation system. As one local farmer explained, *"Subak bukan hanya sistem irigasi, tetapi juga cara hidup dan komunitas yang terorganisir" (Ketua Subak I Wayan Sukerta)*. This statement underscores that the essence of Subak is not only in its agricultural techniques but in its role as a social and cultural framework that binds the community together. The system embodies collective farming practices and reinforces social structures that promote mutual assistance, aligning with broader theories of community-based resource management that emphasize participatory governance (Bignotti et al., 2021; Gadanakis et al., 2024).

The establishment of Subak in Tolai Village was further facilitated by the availability of water resources and the collective will of both Balinese and non-Balinese farmers to engage in cooperative irrigation management. This collaborative effort aligns with research by Gadanakis et al., (2024) on the synergy between local knowledge and modern agribusiness strategies, which points to the importance of integrating traditional practices to create sustainable and resilient agricultural ventures. Furthermore, the adoption of Tri Hita Karana in Subak ensures that the system remains ecologically balanced, fostering long-term sustainability.

Subak Practices and the Value of Tri Hita Karana in Rice Farming

The implementation of the Subak system in Tolai Village is intricately connected to the Tri Hita Karana philosophy, which ensures that agricultural practices not only meet the needs of the present but also foster environmental sustainability and social well-being for future generations. This holistic approach is reflected in the three core components of the Tri Hita Karana philosophy: pawongan (social cooperation), palemahan (environmental harmony), and parhyangan (spiritual connection).

a. Pawongan: Social Cooperation in Subak. The Subak system functions as a social organization where collective action is central to maintaining agricultural productivity. This cooperation is key to ensuring the efficient management of irrigation systems and agricultural tasks such as planting and harvesting. The importance of mutual cooperation, or *gotong royong*, within Subak was emphasized by one farmer: "*Pawongan yang artinya hubungan kita sesama manusia... kalau kita tidak ada teman tidak mungkin bisa kerja sawah sendiri" (Mangku Alit, 1 Februari 2025)*. This notion of working together is consistent with the findings of Pliakoura et al., (2020), which argue that collective action

in agriculture is crucial for enhancing entrepreneurial success and fostering sustainability in rural communities.

b. Palemahan: Environmental Harmony and Sustainable Land Management. In Subak, land and water resources are managed based on communal agreements to ensure that the ecological balance is maintained. As one farmer noted, *"Pengelolaan air dalam subak itu dibuat untuk pembagian adil, supaya semua kebagian" (Petani Subak, Ait Natarianto, 1 Februari 2025)*. This principle of fair water distribution aligns with the research of Mupfasoni et al., (2018), who emphasized that locally adapted water management practices play a vital role in sustaining agricultural productivity while minimizing ecological impacts. Additionally, the farmers' understanding of natural environmental rhythms, such as seasonal changes, is vital for planting decisions, ensuring that farming practices align with nature's cycles (Zen et al., 2024).
c. Parhyangan: Spiritual Connection and Rituals in Subak. Religious rituals and spiritual practices are integral to the Subak system. Ceremonies dedicated to Dewi Sri, the rice goddess, are conducted before planting and harvesting to seek blessings for a bountiful crop. These rituals serve not only as a spiritual connection but also as a reminder of the sacred duty that farmers hold towards the land and the divine. As one Subak leader noted, "*Sebelum turun menanam padi, kami ketua subak dan para anggota subak mengadakan ritual persembahan" (Ketua Subak, I Wayan Sukerta, 3 Februari 2025)*. This spiritual connection to agriculture is deeply embedded in the philosophy of Tri Hita Karana and has been shown to enhance social cohesion and collective responsibility (Gadanakis et al., 2024; Sargani et al., 2020).

In conclusion, the Subak system in Tolai Village exemplifies the harmonious integration of agricultural practices, community values, and spiritual beliefs. It represents a model of sustainable farming rooted in local wisdom that aligns with modern principles of sustainable development and resource management.

Challenges in the Subak System and Strategies for Sustainability

While the Subak system has proven to be effective in maintaining agricultural productivity, several challenges persist that threaten its long-term viability. These challenges are primarily related to environmental factors, infrastructure issues, government policies, and pest infestations. Addressing these challenges requires the continued adaptation of the Subak system through cooperation, knowledge sharing, and the application of sustainable practices.

a. Environmental and Infrastructure Challenges

Irrigation management continues to be a significant challenge, with frequent issues such as damaged irrigation channels hindering the flow of water to crops. As one farmer explained, *"Irigasi jebol itu juga menjadi tantangan bagi petani karena air tidak bisa masuk ke sawah" (Petani Subak, Pak Yuni, 1 Februari 2025)*. These infrastructural challenges, coupled with erratic weather patterns such as floods, pose risks to agricultural stability. *"Banjir juga menjadi tantangan karena bisa merusak padi yang baru ditanam" (Petani Subak, Komang Pujiwan, 1 Februari 2025)*. Such issues align with findings by Abdullah et al. (2020), who identified

the need for improved water management systems and infrastructure to support sustainable agricultural development in rural areas.

To mitigate these challenges, farmers in Tolai Village have implemented strategies such as routine irrigation channel maintenance and the adoption of flood-resistant planting techniques. These adaptive strategies align with broader studies on community-based resource management, which emphasize the importance of collective action in addressing environmental challenges (Bignotti et al., 2021).

b. Pest Infestation and Agricultural Diseases

Pests and diseases, particularly the brown planthopper (*Nilaparvata lugens*), continue to be a major threat to rice cultivation. As one farmer noted, *"Setelah selesai tanam, kendalanya yang kita hadapi adalah hama yang sering merusak tanaman" (Ketua Subak, I Wayan Sukerta, 3 Februari 2025)*. To combat these challenges, farmers in Tolai Village have integrated natural pest control methods and reduced their reliance on chemical pesticides. These approaches are in line with sustainable agricultural practices that emphasize biodiversity conservation and the use of integrated pest management (IPM) techniques (Ionescu et al., 2022; Pliakoura et al., 2023).

c. Government Policies and Farmer Support

Farmers in the Subak system have expressed frustration with the slow response of government support programs. One farmer stated, *"Pengalaman saya selama menjadi petani, pemerintah mengajak bicara, tapi realisasi bantuan sangat lambat" (Petani Subak, Nyoman Suarta, 3 Februari 2025)*. This issue of delayed governmental support has been identified as a significant barrier to agricultural sustainability (Kurtsal et al., 2024). In response, Subak leaders in Tolai have advocated for greater farmer representation in local governance and lobbied for faster implementation of support programs.

Strategies for Sustainability

Despite these challenges, the adaptive strategies within Subak have ensured its continued resilience. Key strategies for sustaining the system include:

a. Knowledge Transfer: Ensuring the younger generation understands and appreciates the Subak system is vital for its survival. As one Subak leader stated, "*Melestarikan subak ke anak-anak kita atau generasi selanjutnya itu penting" (Ketua Subak, I Wayan Sukerta, 3 Februari 2025)*. This focus on intergenerational knowledge transfer aligns with studies on the importance of education in promoting sustainable agricultural practices (Gadanakis et al., 2024; Iyer, 2021).

b. Regular Community Meetings: Routine forums and meetings ensure that community issues are addressed promptly, promoting effective decision-making. *"Kita sering melakukan rapat forum agar masalah di subak bisa cepat diselesaikan" (Petani Subak, Komang Pujiwan, 1 Februari 2025)*.

c. Collective Solidarity: Strengthening cooperation among farmers is crucial for maintaining the integrity of Subak. *"Dengan menjaga kekompakan petani*

subak, kita dapat melestarikannya terus" (Petani Subak, Nyoman Suarta, 3 Februari 2025).

Despite the challenges, the adaptive strategies within Subak emphasize the resilience and determination of the community to sustain their agricultural heritage, ensuring that the principles of the Tri Hita Karana remain at the heart of agricultural practices in Tolai Village.

Interaction and Social-Cultural Integration of Agriculture in Tolai Village

Role of Non-Balinese Ethnic Groups in Subak

The integration of non-Balinese ethnic groups into the Subak system in Tolai Village has played a pivotal role in fostering a more inclusive agricultural community. Initially, the introduction of Balinese agricultural practices, particularly the Subak irrigation system, faced some challenges when adapted by non-Balinese farmers. However, over time, these farmers have not only adopted the core principles of Subak, such as communal irrigation management and collective decision-making, but also contributed to the system's success. As one farmer noted, *"Kami sebagai petani non-Bali ikut serta dalam Subak, beradaptasi dengan aturan yang ada, dan belajar dari cara kerja yang sudah ada" (Petani Subak, Pak Yuni, 1 Februari 2025)*. This illustrates the adaptive capacity of non-Balinese farmers, highlighting their willingness to integrate into a system that, while foreign initially, has provided a sustainable agricultural model.

This process of integration mirrors the findings of research on agricultural entrepreneurship in rural areas, where the combination of local knowledge with externally introduced agricultural practices leads to more resilient farming systems (Gadanakis et al., 2024; Komolafe et al., 2022). In Tolai, the adoption of Subak practices by non-Balinese farmers emphasizes the role of cultural exchange in creating a more dynamic and cooperative agricultural environment. Furthermore, the inclusion of non-Balinese groups in Subak challenges traditional agricultural models and reflects the adaptability of local farming systems in the face of multicultural influences. According to Zen et al., (2024), such integration fosters not only agricultural sustainability but also strengthens community resilience in the face of environmental and economic challenges.

The participation of non-Balinese farmers in Subak has also resulted in a more equitable distribution of agricultural resources and benefits. Through this inclusivity, the Subak system has demonstrated its capacity to overcome ethnic boundaries and create a sense of shared responsibility among farmers. As Gadanakis (2024) suggests, when diverse groups collaborate in agricultural enterprises, it fosters innovation, resource-sharing, and enhanced productivity, all of which contribute to the long-term sustainability of farming practices.

Social Integration of Non-Balinese Ethnic Groups in Subak

The social integration of non-Balinese ethnic groups within the Subak system is a fundamental aspect of its success in Tolai Village. Initially unfamiliar with the formal structures of Subak, non-Balinese ethnic groups gradually embraced its communal values and practices. Over time, these groups have become integral to the system's

social cohesion, contributing to both the productivity and harmony of the farming community. This social integration process is vital for ensuring the sustainability of the Subak system and reflects broader trends in agricultural entrepreneurship, where inclusivity and shared knowledge result in more resilient farming communities (Mupfasoni et al., 2018; Sargani et al., 2020).

Through cultural exchanges and shared labor, the community's social fabric has strengthened, fostering an environment of trust and cooperation. This dynamic is evident in the statement of one of the Subak leaders: *"Kita bekerja sama sebagai satu kelompok, tidak peduli dari mana asal kita, karena tujuan kita sama menjaga Subak dan hasil panen kita" (Ketua Subak, I Wayan Sukerta, 3 Februari 2025)*. This sentiment reflects the collective ethos that underpins the Subak system and aligns with the findings of Gadanakis et al. (2024), who argue that collective decision-making and shared goals are crucial for the success of community-based agricultural systems.

As the social integration of non-Balinese ethnic groups has deepened, these groups have not only adopted Balinese farming practices but have also contributed their own knowledge, enhancing the system's adaptability. This exchange of knowledge and practices reflects the strength of the Subak system as a flexible and evolving agricultural model. The integration of different ethnic groups also underscores the importance of cultural inclusivity in fostering a shared identity and mutual understanding in farming communities. This concept aligns with the broader academic discussion on community-based resource management, where the inclusion of diverse social groups leads to better resource stewardship and improved agricultural outcomes (Bignotti et al., 2021; Gadanakis et al., 2024).

Moreover, the social integration of non-Balinese farmers has strengthened the community's resilience to external pressures, including environmental changes and market fluctuations. The diverse knowledge and practices brought by these groups provide a broader range of solutions to agricultural challenges, enabling the community to adapt more effectively to shifting circumstances. As highlighted by Gadanakis et al. (2024), such cross-cultural cooperation enhances innovation and problem-solving, which are crucial for sustaining agricultural ventures in the long term.

Conflict and Resolution in Water Distribution

Despite the overall success of the Subak system in fostering cooperation, conflicts related to water distribution remain a recurring challenge. Water, being a shared and limited resource, often becomes a point of contention, particularly during critical farming periods such as planting and harvesting. Conflicts arise when water resources are perceived to be unevenly distributed, especially when the needs of different ethnic groups or farming families conflict.

This challenge is not unique to Tolai Village, as many community-based irrigation systems face similar issues (Mupfasoni et al., 2018). However, the traditional mechanisms for conflict resolution within the Subak system ensure that such disputes are handled effectively. Community leaders, such as the Pekaseh (head of Subak), play a crucial role in mediating disputes and ensuring that water is distributed equitably. As one farmer explained, *"Konflik biasanya terjadi ketika air tidak cukup,*

tetapi dengan rapat Subak kami dapat menemukan solusi bersama untuk pembagian air yang adil" (Petani Subak, Komang Pujiwan, 1 Februari 2025). These regular community meetings serve as platforms for open dialogue, where farmers can voice their concerns and negotiate fair solutions. This practice of collective decision-making, grounded in community-based governance, aligns with the principles of participatory resource management outlined by Bignotti et al. (2021) and Zen et al. (2024).

The success of these conflict resolution mechanisms highlights the importance of strong leadership and community involvement in managing shared resources. As noted by Gadanakis et al. (2024), the ability of farmers to resolve disputes collaboratively is a key factor in the sustainability of community-based agricultural systems. The emphasis on dialogue and mutual respect within the Subak system fosters social cohesion and ensures that conflicts are resolved in a way that maintains harmony and equitable access to resources.

Moreover, the role of traditional laws and communal governance structures in resolving water distribution conflicts further strengthens the resilience of the Subak system. These mechanisms are deeply rooted in the cultural values of the community and are an essential part of maintaining the integrity of the Subak system. As Zen et al. (2024) emphasize, traditional governance structures, when effectively implemented, can provide sustainable solutions to resource management challenges.

Knowledge Transfer and Future Sustainability of Subak

Literacy Programs and Educational Initiatives

The transfer of agricultural knowledge is essential for the long-term sustainability of the Subak system in Tolai Village. Ensuring that younger generations understand and appreciate the agricultural practices and cultural values associated with Subak is fundamental to preserving its relevance in the future. One of the main strategies for achieving this knowledge transfer is through literacy programs designed to educate younger generations about Subak's agricultural practices, water management, and the cultural significance of the system. As the head of Subak noted, *"Kita sering mengadakan rapat bersama anggota subak untuk membicarakan bagaimana kita bisa melestarikan subak ke anak-anak kita atau generasi selanjutnya" (Ketua Subak, I Wayan Sukerta, 3 Februari 2025)*. These informal community meetings help younger farmers understand the practical aspects of managing the Subak system, ensuring that they are equipped to continue the traditions of their predecessors.

In addition to these informal meetings, formal educational initiatives play a significant role in ensuring the continued relevance of Subak. Schools and local educational programs have incorporated elements of Subak's philosophy into their curricula, fostering an understanding of sustainable agriculture from a young age. These programs align with the findings of Kurtsal et al., (2024), who emphasize the importance of integrating local knowledge into educational systems, particularly in rural areas where traditional farming practices play a central role. By linking agricultural education with community-based wisdom, these programs help build a strong foundation for the future sustainability of Subak.

Moreover, educational initiatives that teach the value of local wisdom not only preserve agricultural knowledge but also foster a sense of community identity and cultural heritage. This educational approach is essential for ensuring that younger generations do not overlook the importance of sustainable agricultural practices in favor of urbanized lifestyles, which could lead to the loss of valuable traditional knowledge. As noted by Gadanakis et al. (2024), integrating local wisdom into formal education systems plays a crucial role in promoting sustainability in agricultural practices, ensuring that the knowledge is passed down and adapted to modern needs.

Training Initiatives and Involvement in Subak Activities

In addition to formal literacy programs, training initiatives play a crucial role in ensuring that younger generations are equipped with the practical skills needed to manage the Subak system. These initiatives focus on key aspects of agricultural practices, such as rice cultivation, water management, and environmental stewardship, while also imparting leadership skills for roles within the Subak system. As one of the participants in the training program mentioned, *"Kami mengajak anak muda untuk ikut dalam setiap kegiatan Subak, seperti melakukan pembagian air dan membantu di lahan pertanian" (Petani Subak, Komang Pujiwan, 1 Februari 2025)*. Through hands-on involvement in Subak activities, younger generations gain first-hand experience in managing irrigation systems and making decisions related to crop management, which are vital for ensuring the continued functioning of Subak.

This approach of learning by doing aligns with the work of Pliakoura et al., (2020), who argue that experiential learning is essential for cultivating the necessary skills to succeed in agricultural entrepreneurship. The hands-on involvement in Subak activities also provides opportunities for young farmers to learn about the cultural rituals associated with rice cultivation, ensuring that they understand the full significance of the system and are motivated to preserve it for future generations.

Furthermore, the intergenerational exchange of knowledge during training sessions fosters collaboration between older and younger farmers. This collaboration helps bridge the generational gap, ensuring that traditional knowledge is effectively passed down while also allowing younger generations to introduce innovative solutions. This dynamic reflects the research of Komolafe et al., (2022), who highlight the importance of combining traditional and modern practices to foster sustainability in agriculture. In Tolai Village, this integration of old and new farming techniques ensures that the Subak system remains relevant and adaptive to the challenges of the modern agricultural landscape.

Integration of Traditional and Modern Agricultural Practices

In Tolai Village, the integration of traditional agricultural practices with modern technologies has played a significant role in ensuring the continued success and sustainability of the Subak system. While the Subak system is rooted in traditional practices, younger farmers are increasingly exposed to modern farming techniques, tools, and technologies that can enhance agricultural productivity and efficiency. The integration of these technologies, however, does not come at the expense of traditional knowledge. As the head of Subak stated, *"Generasi muda kita harus diajari untuk memadukan teknologi dengan tradisi, agar Subak bisa tetap berkembang, tapi juga*

bisa beradaptasi dengan perubahan zaman" (Ketua Subak, I Wayan Sukerta, 3 Februari 2025). This blending of old and new is crucial for ensuring that Subak remains both sustainable and adaptable in the face of new agricultural challenges, such as climate change and market pressures.

The integration of modern technology with traditional practices is consistent with the findings of Ionescu et al., (2022), who argue that modern technologies can complement traditional knowledge by improving efficiency and productivity while also enhancing sustainability. In Tolai Village, for example, the use of advanced irrigation systems and pest management techniques can support the traditional water-sharing practices within Subak, ensuring a more reliable water supply and reducing the reliance on chemical pesticides. By incorporating these modern tools, Subak farmers are able to enhance their farming practices without losing the cultural and ecological wisdom that has been passed down through generations.

This integration of traditional and modern practices also helps future-proof the Subak system against the challenges posed by climate change. As farming practices become increasingly vulnerable to changing weather patterns, the flexibility of the Subak system allows for the adoption of innovative solutions while maintaining the core principles of sustainability. The work of Zen et al. (2024) reinforces the idea that traditional agricultural systems, when combined with modern innovations, can provide effective responses to environmental challenges, ensuring that communities remain resilient in the face of climate uncertainty.

Role of Community Leaders in Knowledge Transmission

Community leaders play an essential role in the transmission of knowledge within the Subak system. These leaders are not only responsible for managing the irrigation system and overseeing agricultural activities, but also for mentoring younger generations and ensuring that they understand both the technical and cultural aspects of Subak. As one community leader explained, *"Sebagai pemimpin Subak, saya merasa bertanggung jawab untuk menularkan pengetahuan ini ke generasi berikutnya. Mereka yang akan melanjutkan dan menjaga kelestarian Subak" (Mangku Alit, 1 Februari 2025)*. The mentorship provided by community leaders helps to ensure that the values of Subak are passed down in a way that is both relevant and meaningful to younger farmers.

The role of community leaders in knowledge transmission is crucial for maintaining the integrity of the Subak system. Leaders not only provide guidance on agricultural techniques but also instill a sense of cultural pride and responsibility in younger generations. This leadership structure is consistent with the findings of (Sargani et al., 2020), who emphasize the importance of leadership in fostering sustainability in agricultural systems. Community leaders serve as custodians of traditional knowledge, ensuring that future generations are equipped to manage the challenges that arise in the agricultural sector.

Challenges in Knowledge Transfer

While efforts to transfer knowledge are ongoing, there are several challenges to ensuring the effective transmission of traditional agricultural wisdom. One of the key

challenges is the growing influence of urbanization, which has led younger generations to seek alternative livelihoods that are not connected to traditional farming practices. As younger people increasingly move to cities for education and employment, there is a risk that the knowledge and practices associated with Subak may be lost. Additionally, differences in learning styles between older and younger generations, with younger people favoring more modern methods of acquiring information, can hinder the knowledge transfer process.

To address these challenges, community leaders are exploring new ways to make the transfer of knowledge more engaging and relevant to younger generations. This includes using multimedia resources and creating interactive platforms for learning, such as online workshops and community-based training programs. As noted by Kurtsal et al., (2024), integrating modern educational tools with traditional knowledge can help make learning more accessible and engaging, ensuring that younger generations remain connected to their cultural heritage while gaining the skills needed to adapt to modern agricultural challenges.

6. Conclusions

Based on the results and discussion presented, the implementation of local wisdom through the Subak system in Tolai Village demonstrates that this traditional irrigation system not only focuses on improving agricultural productivity but also integrates deep social, cultural, and spiritual values. The local wisdom of Subak, which upholds the Tri Hita Karana principles pawongan (social cooperation), palemahan (harmony with nature), and parhyangan (spiritual connection) plays a vital role in ensuring the sustainability of agricultural practices. By combining traditional knowledge with modern innovations, Subak has proven to effectively address environmental challenges such as climate change while ensuring fair and efficient water distribution.

However, the Subak system in Tolai also faces several challenges, including irrigation infrastructure issues, changing weather patterns, and pest infestations. To overcome these challenges, farmers in Tolai have implemented adaptive strategies such as routine irrigation maintenance and the use of natural pest control methods. Additionally, strengthening the leadership role in Subak management is crucial to ensuring that the values and practices of Subak are passed down to future generations.

The integration of non-Balinese ethnic groups into the Subak system also plays an important role, enriching the cultural diversity and creating a more inclusive agricultural system. Collaboration between different ethnic groups in managing irrigation and making collective decisions reflects the importance of solidarity and effective communication in maintaining the sustainability of agricultural systems.

The transfer of knowledge to younger generations is key to ensuring the future sustainability of Subak. Literacy programs, training initiatives based on Subak activities, and the integration of modern technology with traditional agricultural practices are essential to ensure that Subak remains relevant and adaptive to contemporary challenges. Thus, Subak in Tolai Village is not just an irrigation system but a representation of local wisdom that connects social, cultural, and ecological aspects to create resilience and sustainability in agricultural entrepreneurship.

Overall, the integration of local wisdom into sustainable agricultural entrepreneurship in Tolai Village shows that community-based approaches and the preservation of cultural heritage can offer effective solutions to modern agricultural challenges. Subak serves as a successful example of combining local knowledge with technology and resource management to enhance agricultural output while maintaining ecological and social balance.

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