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Developing Subak Capacity in Facing the Challenges of Modern Agriculture and Climate Change in Bali

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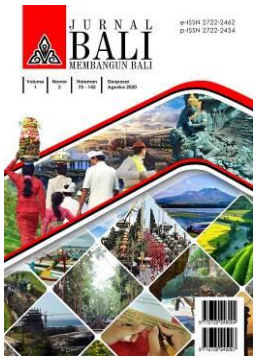

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Abstrak
Tujuan: Penelitian ini bertujuan untuk menganalisis tantangan yang dihadapi sistem irigasi tradisional Subak di Bali dalam menghadapi perkembangan pertanian *modern* dan dampak perubahan iklim, serta mengidentifikasi strategi yang dapat digunakan untuk mengatasi tantangan tersebut.
Metode penelitian: Metode penelitian yang digunakan adalah pendekatan normatif kualitatif dengan analisis literatur, dokumen kebijakan, dan data sekunder yang relevan. Penelitian ini juga melibatkan pendekatan deskriptif-evaluatif untuk menggambarkan kondisi Subak serta potensi dan kendala yang dihadapinya.
Hasil dan pembahasan: Subak perlu mengadopsi teknologi pertanian *modern* yang sesuai dengan nilai-nilai kearifan lokal, serta meningkatkan kapasitas adaptasi terhadap perubahan iklim melalui penyesuaian pola tanam, penerapan teknologi ramah lingkungan, dan penguatan kelembagaan.
Implikasi: Implikasi dari penelitian ini adalah perlunya dukungan kebijakan yang komprehensif dan pendidikan berkelanjutan bagi petani untuk memastikan keberlanjutan Subak sebagai sistem irigasi tradisional yang mampu menghadapi tantangan modernisasi dan perubahan iklim, sehingga tetap berperan sebagai fondasi utama pertanian di Bali.

Kata kunci: subak, teknologi pertanian modern, perubahan iklim

Abstract
Purpose: This study aims to analyze the challenges faced by the traditional Subak irrigation system in Bali in facing the development of *modern* agriculture and the impacts of climate change, and to identify strategies that can be used to overcome these challenges.
Research methods: The research method used is a qualitative normative approach with analysis of literature, policy documents, and relevant secondary data. This study also involves a descriptive-evaluative approach to describe the condition of Subak and the potential and constraints it faces.
Results and discussion: Subak needs to adopt *modern* agricultural technology that is in accordance with local wisdom values, as well as increase the capacity for adaptation to climate change through adjustments to cropping patterns, application of environmentally friendly technology, and strengthening institutions.
Implication: The implication of this study is the need for comprehensive policy support and ongoing education for farmers to ensure the sustainability of Subak as a traditional irrigation system that is able to face the challenges of *modern*ization and climate change, so that it continues to play a role as the main foundation of agriculture in Bali.

Keywords: subak, modern agricultural technology, climate change

INTRODUCTION

Subak is a traditional irrigation system that has long been the backbone of agriculture in Bali (Arti, 2024). Known for its strong organizational structure and underlying collective values, Subak not only functions as a water distribution system, but also as a guardian of local wisdom that unites agricultural, social, and spiritual aspects (Lestari *et al*., 2023). This system has been recognized by UNESCO as a

World Cultural Heritage, showing how important Subak is in preserving Balinese culture and its natural environment. However, amidst this global recognition, Subak faces various challenges that threaten its sustainability (Widayanto, 2020).

Modern agriculture brings with it various new technologies and methods that aim to increase productivity and efficiency (Putri *et al*., 2023). However, the application of this technology is often not in line with the principles of Subak which uphold the balance between humans and nature. Agricultural modernization that is not balanced with a deep understanding of local dynamics can cause environmental damage and declining soil and water quality (Rosmalah *et al*., 2024). In addition, the introduction of new crop varieties that focus on high yields often ignores aspects of long-term sustainability and local food security (Reuter & MacRae, 2024).

On the other hand, climate change is a major challenge for the whole world, including Bali. Changing weather patterns, increasing temperatures, and changes in the cycle of rain and drought have a direct impact on the agricultural sector. Subak, which relies on traditional weather predictions and stable water patterns, now has to face increasing uncertainty (Anggraini *et al*., 2024). Without adequate adaptive capacity, Subak is at risk of losing its function as a support for the lives of farmers in Bali. Climate change also exacerbates existing problems, such as soil erosion and desertification, which can significantly reduce agricultural land productivity (Styawan, 2022).

In facing these challenges, Subak capacity development is very important. The capacity in question includes the ability to integrate modern, environmentally friendly agricultural technologies, increase resilience to the impacts of climate change, and strengthen the values of local wisdom that are the basis of the Subak system itself. This capacity development must also involve collaboration between various stakeholders, including government, academics, farmers, and local communities, to ensure that Subak can continue to survive and function effectively in the future.

The importance of developing Subak capacity is also closely related to efforts to preserve Balinese culture and environment as a whole (Lasaiba, 2022). Subak is not only an irrigation system, but also a symbol of a harmonious balance between humans and nature, which is the basis of Balinese life (Saihu, 2020). Therefore, maintaining the sustainability of Subak means maintaining the cultural and environmental heritage that has been passed down from generation to generation.

This capacity building effort must begin with an in-depth assessment of the challenges faced by Subak in the context of modern agriculture and climate change. Identification of existing strengths, weaknesses, opportunities, and threats will be the basis for formulating a comprehensive and sustainable development strategy. This strategy must include technical, social, and economic aspects, and consider the ever-evolving global and local dynamics.

Thus, developing Subak's capacity to face the challenges of modern agriculture and climate change is not only a necessity, but also a shared responsibility to maintain the sustainability of culture, environment, and the sustainability of the agricultural economy in Bali. This challenge requires a holistic and innovative approach, as well as a strong commitment from all parties involved. Thus, Subak will remain a solid foundation for Balinese agriculture in the future, as well as a model for other traditional agricultural systems around the world.

RESEARCH METHODS

This study uses a normative research type, which aims to analyze the traditional Subak irrigation system in the context of the challenges of modern agriculture and climate change based on the norms, values, and principles inherent in Balinese society. This study uses a qualitative approach to examine how traditional values contained in the Subak system can adapt to the demands of modernization and climate change. The data used comes from a literature review that includes scientific literature, regulatory documents, and previous research related to Subak, modern agriculture, and adaptation to climate change. Collection of secondary legal materials obtained from various sources, including academic journals, books, government reports, regulations and policies related to Subak, as well as studies on climate change and agricultural technology. This data is used to understand the legal and normative framework that influences Subak management. Analysis was carried out on various policy documents and regulations related to the Subak system and agricultural management in Bali. This is done to evaluate whether existing policies and regulations already support Subak's adaptation to the challenges of modern agriculture and climate change. This analysis is also used to identify policy gaps that need to be fixed in order to support the sustainability of the Subak system.

This study uses a descriptive-evaluative method to describe the conditions and challenges faced by Subak and to evaluate the extent to which local wisdom in this system is able to adapt to modernization and climate change. Through this approach, a picture is obtained of the potential and constraints in integrating modern technology into the Subak system as well as efforts to increase the capacity for adaptation to climate change. By using this normative approach, the study is expected to provide a deeper understanding of the importance of preserving local wisdom in the Subak system while adapting to environmental changes and modern challenges. The results of this study are also expected to provide input for the government and stakeholders in formulating policies that support the sustainability of Subak as a unique and important traditional irrigation system in Bali.

RESULTS AND DISCUSSION

The Way how Subak Integrates Modern Agricultural Technology without Sacrificing Local Wisdom Values and Environmental Sustainability

Subak is a traditional irrigation system in Bali that not only regulates water distribution but also reflects deep local wisdom about the relationship between humans, nature, and spirituality (Shohibuddin, n.d.). Subak is rooted in the philosophy of Tri Hita Karana, which emphasizes the balance between three main elements: the relationship between humans and God, humans and nature, and humans and fellow humans (Sukmayasa & Mahardika, 2024). This system has been running for centuries, preserving the environment while supporting the socio-economic well-being of farming communities. However, in the era of globalization and modernization, Subak faces major challenges in maintaining its identity and function. Modern agricultural technology, with all its advantages in increasing productivity and efficiency, is often not in line with the principles of Subak (Suryana *et al*., n.d.). The application of technology such as agricultural machinery, intensive use of chemical fertilizers and pesticides, and

the introduction of new superior plant varieties, although it can increase yields in the short term, can have long-term detrimental impacts on the local ecosystem (Sari *et al*., 2024). The use of chemical fertilizers and pesticides, for example, can cause soil degradation and pollution of water sources, which ultimately threatens the sustainability of the Subak irrigation system itself.

Subak, which has relied on organic and environmentally friendly farming practices, faces a dilemma when faced with the need to increase productivity to meet increasing market demand. On the one hand, there is pressure to adapt to technological developments in order to remain competitive in the global market. On the other hand, there is concern that the application of inappropriate technology will damage the values of local wisdom and the ecological balance that has long been maintained. Therefore, the main question that arises is how Subak can integrate modern technology without sacrificing the basic principles that have been the foundation of its existence for centuries. One approach that can be taken is to choose technology that is environmentally friendly and appropriate to local conditions (Gusfira, 2024). Modern agricultural technology does not always have to conflict with traditional values; on the contrary, if chosen and applied wisely, technology can strengthen and improve the sustainability of Subak (Supartono *et al*., 2024). For example, the use of drip irrigation technology that is more efficient in water use, or the development of local rice varieties that are more resistant to pests and diseases without the need for the use of chemical pesticides, can be solutions that are in accordance with the Tri Hita Karana philosophy.

In addition, education and training for farmers on new technologies that are in accordance with Subak principles are essential. Farmers must be given an understanding of how these technologies can be applied without damaging the environment or disrupting the existing socio-cultural balance. This training should cover technical aspects, but also pay attention to the values of local wisdom that are an integral part of Balinese life. Thus, farmers can become agents of change who are able to integrate modern technology into their agricultural practices without losing their identity as part of the Subak community.

In addition, collaboration between the government, academics, and local communities is essential to support the integration of this technology. The government can play a role in providing incentives for farmers who use environmentally friendly technology, while academics can contribute through research and development of technologies that are appropriate to local needs. Local communities, as guardians of traditional wisdom, need to be actively involved in the decision-making process so that every innovation that is implemented does not set aside values that have been passed down from generation to generation (Mesra, 2023).

No less important is the development of policies that support the sustainability of Subak amidst the pressures of modernization. The government needs to formulate policies that not only encourage the adoption of modern technology but also ensure that the technology does not damage local ecosystems or cultures (Sarjito, 2023). These policies should include protection of agricultural land from unsustainable conversion, equitable management of water resources, and support for environmentally friendly and sustainable agricultural practices.

In facing these challenges, Subak has the potential to become an innovative model in the integration of modern technology and local wisdom (Puspitasari *et al*., 2024). If managed properly, Subak can show the world that modernization does not

have to mean abandoning local traditions and wisdom. Instead, through a sustainable and inclusive approach, Subak can continue to develop and adapt to changing times, while maintaining the values that have made it a world cultural heritage.

In conclusion, the integration of modern agricultural technology into the Subak system must be done carefully, considering the long-term impacts on the environment and local culture. Through the right choice of technology, farmer education, collaboration between stakeholders, and continued policy support, Subak can continue to be the foundation of strong and sustainable Balinese agriculture. Thus, Subak will not only survive the challenges of modernization, but will also thrive as an example of success in maintaining the balance between innovation and tradition.

Adaptive Capacity of Subak to Face the Impacts of Climate Change Affecting Irrigation Systems and Agricultural Productivity in Bali

Subak, as a traditional irrigation system that has been around for hundreds of years in Bali, is an example of local wisdom that is able to maintain the balance between humans and nature. This system not only regulates the distribution of water for agricultural purposes, but also maintains social, cultural, and spiritual relationships in Balinese society. However, in an era of increasingly uncertain climate change, Subak faces major challenges that threaten its sustainability. Changes in weather patterns, increasing global temperatures, and the intensity of natural disasters such as floods and droughts are some of the real impacts of climate change that need to be anticipated by the Subak system (Sulaminingsih *et al*., 2024). Climate change has caused significant changes in weather patterns in Bali, which directly affect the Subak irrigation system (Harahap *et al*., 2023). Subak, which has relied on traditional weather predictions and stable water cycle patterns, now has to deal with increasing uncertainty. For example, the rainy season that comes too late or too early, as well as irregular rainfall intensity, can disrupt the established planting cycle. As a result, farmers have difficulty in determining the right planting time, which in turn has an impact on agricultural productivity.

In addition, increasing global temperatures also affect water availability in Bali (Susanto *et al*., 2024). Water, which is a key element in the Subak system, is now increasingly difficult to regulate due to changes in river flows and the availability of water sources. Prolonged droughts can cause water shortages, while floods due to heavy rain can damage irrigation infrastructure and agricultural land. Subak, which has long been considered a stable and reliable irrigation system, now has to face new risks caused by climate change.

In this context, increasing the adaptive capacity of Subak is an urgent need (Surono & Hidayati, 2024). Adaptive capacity refers to the ability of Subak to adapt to environmental changes that occur, either through changes in water management, planting patterns, or other strategies that can help this system survive amidst climate change.

Increasing the adaptive capacity of Subak can be done through several approaches below.

1. Adjustment of Cropping Patterns and Agricultural Diversification

One important step in increasing Subak's adaptive capacity is to adjust planting patterns according to climate change. If previously farmers in Bali followed a fixed planting pattern based on stable rainy and dry seasons, now they need to be more

flexible in adjusting planting times and types of crops planted. Crop diversification is also important to increase resilience to extreme weather conditions. By planting various types of crops that have different water requirements and resistance to weather, farmers can reduce the risk of crop failure due to climate change.

2. Implementation of Environmentally Friendly Technology

Environmentally friendly agricultural technology can help Subak manage water resources more efficiently. For example, drip irrigation or micro irrigation technology can be used to save water use, especially in areas prone to drought. In addition, the development and use of rice varieties that are more resistant to drought or flooding can help farmers deal with unpredictable weather conditions. The use of this technology must be accompanied by adequate training so that farmers can apply it correctly without damaging the local ecosystem.

3. Institutional Strengthening and Cooperation between Stakeholders

Subak's adaptive capacity can also be improved through institutional strengthening. Subak institutions, which have been strong in social and spiritual aspects, need to be strengthened in terms of natural resource management and adaptation to environmental change. This includes more efficient water management, monitoring of weather changes, and better coordination between Subak members in dealing with natural disasters. In addition, cooperation between the government, academics, and local communities is very important in formulating policies and strategies that support Subak's adaptation to climate change. The government can provide accurate and up-to-date weather data, while academics can play a role in research and development of innovative adaptation solutions.

4. Education and Extension for Farmers

Continuous education and extension are very important in improving Subak's adaptive capacity. Farmers need to be given a deep understanding of the impacts of climate change and how they can cope with them. Extension on the use of new technologies, adjustments to cropping patterns, and ways to mitigate the impacts of climate change must be part of routine programs organized by the government or related institutions. Through this education and outreach, farmers are expected to be more prepared and responsive in facing climate change, and able to implement practices that support the sustainability of their agriculture.

5. Development of Early Warning Systems and Risk Management

Subak also needs to be equipped with an early warning system that can detect extreme weather changes, such as heavy rain or prolonged drought. With this early warning system, farmers can take preventive measures earlier to reduce the negative impacts of natural disasters. In addition, planned risk management is also important to help farmers deal with losses that may arise due to climate change. The government and financial institutions can play a role in providing agricultural insurance or financial assistance for farmers affected by natural disasters.

6. Development of Infrastructure that is More Resilient to Natural Disasters

In facing climate change, Subak irrigation infrastructure needs to be improved to be more resilient to natural disasters such as floods or landslides. The construction or repair of stronger and more sustainable dams, water channels, and terracing will

help maintain water availability and prevent further damage to agricultural land. Investment in this infrastructure must be based on a comprehensive risk analysis and take into account future climate change projections.

Through these approaches, Subak's adaptive capacity can be significantly improved. Thus, Subak will not only be able to survive in the midst of increasingly extreme climate change, but can also continue to be a strong foundation for agricultural sustainability in Bali. Success in improving Subak's adaptive capacity will provide a valuable example for other traditional agricultural systems around the world in facing the challenges of global climate change. It will also show that local wisdom, if well managed and adapted to the times, remains relevant and can contribute significantly in facing modern challenges.

CONCLUSION

Based on the analysis of the two problem formulations, it can be concluded that Subak, as a traditional irrigation system rich in local wisdom values in Bali, faces major challenges in dealing with modern agriculture and climate change. To ensure the sustainability of Subak, a careful and integrated approach is needed in adopting modern technology and increasing the capacity for adaptation to climate change. First, in facing agricultural modernization, Subak needs to integrate environmentally friendly technology without sacrificing the traditional values that are the foundation of this system. This can be achieved through the selection of appropriate technology, education for farmers, and collaboration between stakeholders to ensure that the innovations implemented remain in line with the principles of sustainability and local wisdom. In this way, Subak can remain relevant and productive in the modern era, while maintaining the cultural and environmental identity that has been passed down from generation to generation.

Second, in facing the impacts of climate change, increasing the adaptive capacity of Subak is key to maintaining the sustainability of this system. This includes adjusting cropping patterns, implementing environmentally friendly technologies, strengthening institutions, and continuing education and counseling for farmers. In addition, developing disaster-resistant infrastructure and early warning systems are also important to help Subak deal with the risks posed by climate change. Through these steps, Subak can continue to function optimally, even when faced with increasingly unpredictable weather conditions. Overall, Subak has great potential to be an example of how traditional agricultural systems can adapt and thrive amidst the challenges of modernization and climate change. With a holistic and sustainable approach, Subak can continue to play a major role as a mainstay of agriculture in Bali, while maintaining its cultural heritage and the balance of the ecosystem that characterizes it.

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