

# Pentahelix-Based Integrating Strategy for Sustainable Green Agriculture as an Eco-innovation Model in Karangasem, Bali

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**Abstract.** This study explores an eco-innovation model for advancing sustainable green agriculture in Karangasem Regency, Bali through the integration of pentahelix collaboration. As agricultural landscapes face increasing pressures from climate variability, land degradation, and limited technological adoption, effective strategies are required to enhance ecological resilience and support environmentally responsible farming system. The research adopts a qualitative case study method, focusing on the synergy among key actors in the Pentahelix model: government, academia, business, civil society, and media. The findings indicate that collaborative mechanisms play a significant role in strengthening sustainable land management, introducing low-carbon agricultural technologies, and promoting community based ecological practices. Furthermore, the study highlights that green agriculture transitions are most successful when supported by shared environmental goals, local ecological knowledge, and stakeholder that engaged with the environmental program. This study contributes to the broader discourse offering the evidence-based insights into enhancing the adoption, scaling up, and long-term viability of eco-friendly farming systems. **Keywords:** Pentahelix, sustainability, green agriculture, collaborative governance.

## 1 Introduction

The agricultural sector remains a critical foundation for ensuring food security, environmental sustainability, and rural economic development especially in regions like Karangasem regency. However, the traditional farming which used methods facing more problem caused by climate change, damaged land, waste of resources, and some change of society in the context of economy [1,2]. To deal with increasing some issue, green agriculture has become more as a new and complete way to combine sustainable farming, environmental protectin, and the use of technology [3]. Green agriculture is described as a type of farming which tries to find a balancing between producing food and protecting environment [4]. It should encourage many things like organic farming, protecting different types of plants and animals, also saving soil and water, and helping farmer to have a better wealthiness [5,6].

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When green agriculture is part of smart agriculture plans, it becomes a key to improving resilience to climate change and encouraging circular economies in long term sustainability goals [7]. Even though green agriculture is becoming more important nowadays, it's hard to put into practice in developing areas like Indonesia [8,9]. Several challenges were identified including limited digital literacy and access to digital tools, weak organizational capacity and also the absence of unified plan that enables stakeholders to collaborate while maintaining sustainable outcomes. In addition, the community engaged in green agriculture lacks sufficient empowerment to make independent decisions, they tend to rely heavily on leaders and experts to ensure that the initiatives remain on track [10].

The pentahelix model offers a potential solution for addressing management challenges among the government, academia, business sector, community groups, and the media [11–13]. This model encourages shared responsibility and collective knowledge-building. Enabling stakeholders to distribute roles more effectively in implementing sustainable agricultural project. However, there has been limited research on how local governments apply the pentahelix model in the context of green agriculture, particularly in rural and culturally rich regions as Karangasem [12,14]. This research explores the gaps by analysing the strategy which adopted by Karangasem's government in developing sustainable green agriculture through the pentahelix approach. It seeks to understanding how the local government engage with stakeholders especially in the form of pentahelix.

## **2 Literature Review**

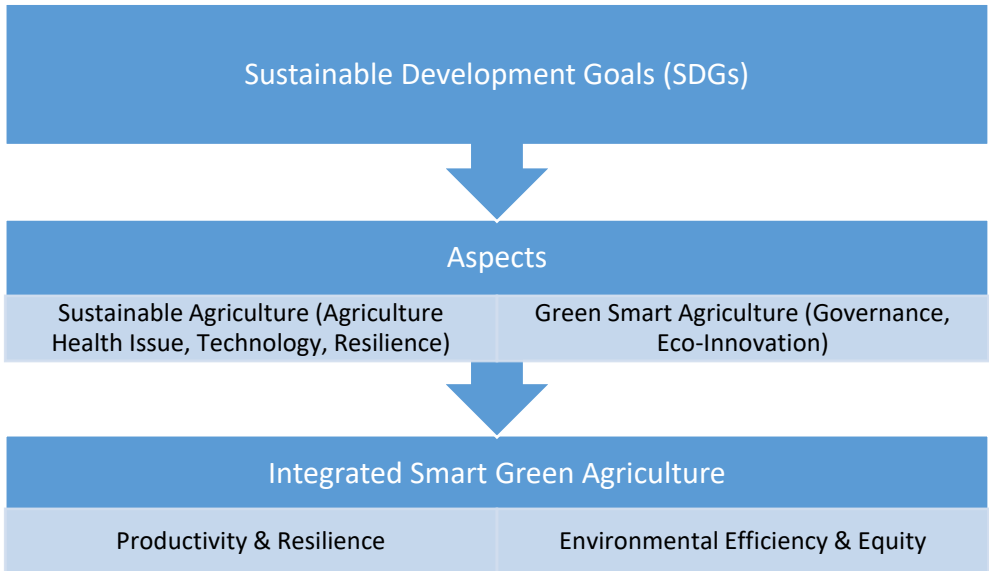
### **2.1 Sustainable Agriculture**

Sustainable agriculture is a way of farming that provides good food and material enough without making it difficult for future generation. It focuses on how using natural resources and keeping soil healthy for a long-term causing as little harm to the environment as possible. Ensuring fair economic value and social condition for farmer community is also part of sustainable agriculture. an important part of sustainable agriculture is put climate smart agriculture technology as part of how we arrange the sustainable agriculture. Sustainable agriculture is also part to improving productivity while preserving the environment and enhancing the resilience of farmer to climate shocks. However, sustainable agriculture in the Sahel faces significant barriers such as limited access to knowledge, financing, and market systems particularly in peri-urban zones that are often excluded from rural development initiatives.

### **2.2 Environmental Concept in Smart Agriculture**

Environmental concept in smart agriculture refers to the integration of environmentally conscious practices with digital and technological innovations to enhance sustainability, resilience, and productivity. This involves using green technologies such as solar-powered irrigation, digital monitoring in crop health, and smart resource management systems that align with the goals of climate adaptation and mitigation. Green smart agriculture policies must be tailored to specific ecological and socio-economic contexts. The literature also underscores the gap in governance frameworks that adequately address the unique needs of peri-urban agriculture. While “climate-smart villages” have been studied extensively, the adaptation such models to semi -urban or transition zones is still limited. Therefore, advancing the eco-friendly farming system requires approaches that are decentralized, and sensitive to local environmental dynamics. Collaboration of multi-stakeholders can

strengthen ecological innovation by bringing together knowledge from multiple sectors to support environmentally sustainable practices.



**Fig. 1.** Sustainable Development Goals for Smart Agriculture Concept.

As shown in the figure 1, there is any conceptual framework that align the sustainable development goals and the integrated smart green agriculture to support the efficiency and equity of environmental productivity especially the area of agriculture. However, challenges remain, particularly in the Sahel and peri-urban areas, where limited access to knowledge, financing, and market systems hinders adoption (as shown in figure 1). Thus, sustainable agriculture requires systemic integration with broader development policies to overcome structural barriers. To address this issue, a Pentahelix governance approach is suggested to this research to involving multi-stakeholder collaboration. This model ensures that green-smart agriculture is not only environmentally sound but socially inclusive and institutionally sustainable.

### 3 Methodology

This research employs a qualitative descriptive approach to analyze how the pentahelix-based integrating strategy to support the advancement of sustainable smart agriculture in Karangasem Regency. This research contributes to strengthening eco-friendly farming practices, enhancing agro-ecological innovation, and promoting environmentally resilient agricultural system. The methodological framework consists of two main component which literature review and field observation, together provide a comprehensive understanding of both theoretical foundations and empirical realities. The literature review was conducted to explore the theoretical concepts and empirical findings related to sustainable agriculture, green policy, and collaborative governance models. To contextualize and validate the findings from the literature, direct field observations were focused on the roles and interaction of various stakeholders which government agencies, farmers, academia, and local media. By combining literature-based analysis with field observation. This study ensures a well-rounded

understanding of how sustainable green agriculture is conceptualized, operationalize, and governed at the local level.

This research is using literature review to undertaken theoretical concept related to sustainable agriculture, green policy, smart agriculture practice, and collaborative governance model to ensure the conceptual lens for analyzing this research. Field observation that conducts to this research in Karangasem Regency Bali Indonesia, on March 2024. The observation focused on how agricultural zones are being implemented within the smart city framework, particularly in relation to green smart farming initiatives. The participants involved in this study were selected based on a multi-stakeholder group, consisting of government agencies, community representatives, academia, the private sector, and local media to capture a comprehensive lens of the smart city. Data were collected through semi-structured interviews with stakeholders. The data were then analyzed using thematic analysis in which interview transcripts, observation notes, and relevan documents were coded to identify emerging patterns.

## **4 Result and Discussion**

This research findings shows that Karangasem regency putting sustainable green farming into practice in showing how the five parts of pentahelix model work together which specifying into government, academia, businesses, community, and media. These stakeholders work together through official projects and casual connection to help environment, farming and protecting the culture of being farmer in rural era in the era of technology. The Quick Win programs which started between 2023 and 2024 provide empirical evidence of multi-stakeholder collaboration in action, revealing distinct roles and varying levels of influence among actors. The government particularly the Karangasem Department of Agriculture and Environmental Services, acts as the lead initiator and regulator, holding the most dominant role within the Pentahelix structure. It establishes regulatory frameworks, allocates budgets for organic input subsidies, and coordinates stakeholder forums. Through flagship polit projects in Bebandem and Selat sub-districts, the government introduced climate adaptive seed and permaculture-based land-use planning, serving as a catalyst for innovation adoption. Complementing this, academic institution such as Udayana University and local agricultural polytechnics function as knowledge providers and evaluators. Their contributions include conducting soil health assessments, training farmers in biofertilizer production, and evaluating the impacts of sustainable practices. Their role is critical in bridging scientific research with local wisdom, particularly in applying the ecological values of Tri Hita Karana.

The business sector, though less dominant, plays an enabling role in scaling technology and expanding market access. Agritech startups and farmer cooperatives provide IoT-based irrigation systems, support the development of eco-agro tourism initiatives, and create green value chains. However, their involvement remains limited to select areas and depends heavily on public sector facilitation. Civil society organizations, including subak (traditional water user associations) and women's farming groups, serve as grassroots implementers and environmental stewards. They disseminate indigenous knowledge, mobilize community-based composting and reforestation efforts and advocate for their fair access to agricultural support. Despite their hands on role in field level execution, they are often positioned as recipients rather than co-creators in strategic decision making. All data qualitative in this research were imported into NVivo software, each data segment referring to the influence stakeholder group was coded under corresponding thematic nodes.

The table 1 shown that the functional contributions of each stakeholder group involved in the implementation of sustainable green agriculture, as observed in Karangasem regency. They help amplify success stories and foster public awareness of green agriculture initiatives.

**Table 1.** Pentahelix Roles and Interaction in Karangasem.

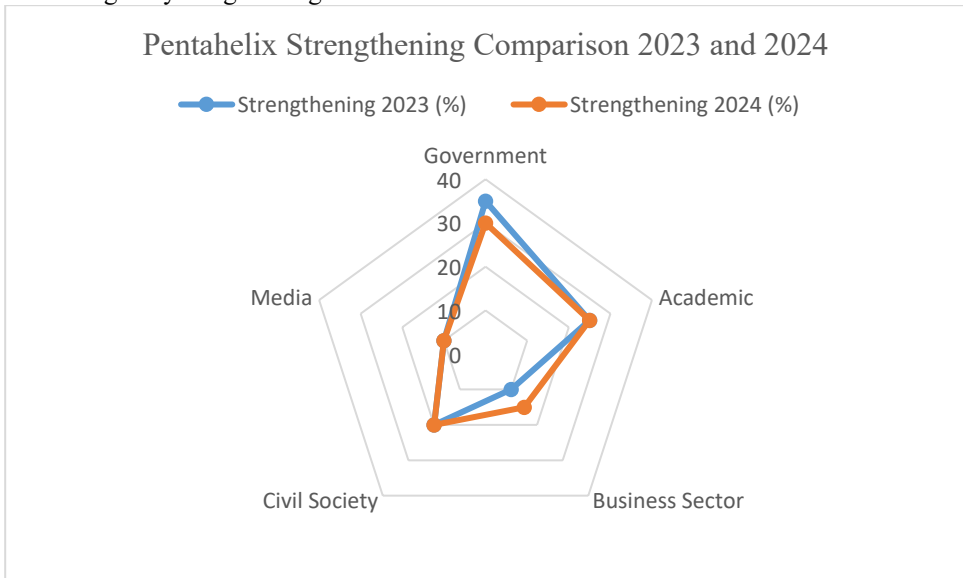
<b>Pentahelix</b>	<b>Primary Role</b>	<b>Key Activities</b>	<b>Dominance (%)</b>
Government	The government as enabler of ecological standar and environmental safeguards	Supporting green technology subsidies in term of climate resilient agriculture program	30
Academia	as the pillar of eco-innovation and environmental diagnostic	The activity is related with soil-water quality inspection, formulating biofertilizer, and low-carbon farming techniques	25
Business Sector	Provider of green technologies and sustainable value chains	In supplying the solar-powered irrigation and also IoT based environmental monitoring tools	15
Civil Society	Grassroots implementer, knowledge disseminator	Water-soil knowledge transfer, composting, lobbying	20
Media	Amplifier of environmental awareness and sustainable behavioral	Driving digital environment campaigns	10

Source: Primary Data 2024

It categorizes the five pentahelix actor, such as, *first*, government as the most dominant actor functioning as the policy initiator, regulator, and program funder. Its key activities include policy design, launching pilot programs, and allocating resources for program implementation. Second, academia serving as a scientific advior and training provider. They contribute through activities such as soil assessments, capacity building on biofertilizer production, and evaluation of agricultural practices. Third, the business sector acting as a technology provider, market enabler, and tourism collaborator. Their roles include supplying IoT based irrigation systems and supporting the development of agrotourism and organic supply chains. Forth, civil society represent the grassroots level in focusing on traditional water-soil management practices and advocating for the interests of smallholder farmers. Fifth, media plays an information and engagement role. The dominance values presented in Table 1 were calculated using NVivo 12 software. The dominance was determined by calculating the proportion of coded references for each stakeholder group relative to the total coded references. This process reflects both frequency and intensity of stakeholder involvement, ensuring that the quantified percentages capture the relative functional contribution of each Pentahelix actor in the development of sustainable green agriculture.

Media outlets and social media networks play a supporting role by raising public awareness, documenting field success stories, and encouraging behavioural change, particularly among youth farmers. While their influence on strategic planning is minimal, they are crucial in amplifying narratives of sustainable transition and legitimizing green agriculture efforts. The interaction among these actors reveals an emerging governance ecosystem in Karangasem. Government and academia continue to dominate agenda setting processes, while civil society and business actors contribute primarily to implementation. These achievements signal the operational potential of a contextualized Pentahelix

framework. Nevertheless, further refinement is required to deepen co-creation in policy design, expand private sector engagement and strengthen digital inclusion. These steps are essential to transform Karangasem into a model regency for sustainable, locally embedded, and technologically integrated agriculture.



**Fig. 2.** Pentahelix Strengthening Comparison 2023 and 2024.

Figure 2 shown that the comparison roles of government, academia, business sector, civil society, and media evolved over the two-year period. This strengthening slightly decreased to 30% in 2024 indicating a gradual redistribution of responsibilities and increased involvement from other stakeholders. Overall, the figure 1 reflects a gradual but meaningful shift toward a more balanced multi stakeholder model with increased participation from non-state actors, especially the private sector while the government begins to reposition itself as a facilitator rather than a sole driver of green agricultural governance.

## 5 Conclusion

This study concludes that the implementation of sustainable green agriculture in Karangasem demonstrates the growing relevance and operational viability of the Pentahelix collaboration model. Amid the challenges of climate change, ecological degradation, and fragmented institutional coordination, Karangasem has taken significant strides toward adopting a locally integrated, technologically adaptive, and ecological responsibility. Through the strategic roles of thus actors, the region has begun shifting from conventional top-down interventions to a more inclusive, participatory, and decentralized approach. For Karangasem to mature into a model for sustainable agriculture governance, further improvements are needed namely in co-creation mechanism, digital infrastructure, and incentives for private sector engagement.

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