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Original article

ANDONGAN AS A STRATEGY FOR PURIFYING AGRICULTURAL IRRIGATION WATER: CASE STUDY OF SUBAK SEMBUNG, BALI

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Abstract

Farmers in Bali have for centuries applied local wisdom in the concept of andongan to obtain better water quality from Subak irrigation streams. The problem is that the implementation of andongan is starting to be abandoned because farmers do not understand the benefits and functions of andongan. This research aims to analyze the local wisdom in the andongan concept in Subak Sembung, Denpasar-Bali, and identify the plants used in andongan. The target is that the andongan concept can be revitalized so that it can be implemented again by farmers. Moreover, the idea of andongan in terms of its function, purpose, and how it works in principle is the same as phytoremediation technology. The case study method with a qualitative approach was used in this research to collect data through observation, interviews, and documentation. If examined closely, andongan is a water management system that reflects Balinese farmers' respect for water as a source of life. Water is respected as a vital element for producing food and maintaining the sustainability of the agricultural sector. Conceptually, andongan is a water purification innovation using plants commonly referred to as phytoremediation technology. The types of plants commonly used to purify water in andongan are water hyacinth (*Eichornia Crassipes*) and lotus (*Nymphaeae sp.*). The implementation of the Andongan concept in Subak currently faces challenges related to farmers' land ownership status. Tenant farmers who do not have permanent ownership of the land they manage are reluctant to build Andongan because they are worried that this will reduce the size of the planting area and result in a decrease in crop yields. Based on the results of the study, it can be concluded that farmers in Bali have been applying phytoremediation technology for centuries in a water management concept called Andongan. The plants used in andongan also have benefits as animal feed and for religious ceremonies.

Keywords: Andongan; Bali; Local Wisdom; Subak Sembung; Water Purification

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Introduction

The existence of Subak in Bali is believed to have existed since the early ninth century. For a long time, Subak has successfully managed and utilized water sources for irrigation [1]. Subak guarantees fair distribution of water to farms, maintains irrigation systems, mobilizes resources and mutual aid, resolves conflicts, and ensures the implementation of rituals [2]. The Subak system has made the Balinese people the most productive rice farmers in Indonesia and guaranteed a high level of food sovereignty for the island's dense population [3].

Subak has been recognized as a world cultural heritage by UNESCO since 2012. The sustainability of the system and the existence of Subak in the future is of great concern. There are several challenges in Subak conservation, one of which is reducing the number of Subak areas and deteriorating the quality and quantity of water resources. Another problem is that farmers are over 40 years old with heavy financial burdens and the absence of clear external regulations to support Subak conservation [4]. The fragile Subak system is threatened by its complexity and linkages with new agricultural practices and increased tourism on the island of the gods [3]. The development of tourism activities has had a significant influence on the reduction of rice fields. This is a challenge to maintain its title as part of the world cultural heritage landscape [5].

Subak is a local organization that implements traditional Balinese ecological knowledge and wisdom in managing and distributing water for agricultural purposes [6]. As an irrigation system management association, the Subak association has naturally adapted to participatory irrigation management [7]. Apart from having a role in regulating the distribution and allocation of irrigation water, Subak also plays a role in regulating planting patterns and annual planting schedules. Another role is mobilizing resources for irrigation, agriculture, social and cultural activities, and ritual ceremonies [8].

Subak is a local wisdom in Bali that has been practiced for centuries in managing irrigation water. Irrigation water management in Subak is quite promising to support food sustainability in the region [9]. The Balinese people have long been conserving water resources and managing water quality through various forms of local wisdom. Local wisdom is passed down from generation to gener-

ation in routine activities of daily life [10]. One of the water quality management efforts that has long been practiced by Subak farmer members is purifying irrigation water using a form of local wisdom called andongan. The andongan concept is still implemented today by farmers in Subak Sembung, Denpasar-Bali.

Increasing use of irrigation water has led to a decline in water and soil quality in many areas. Natural and synthetic nanoparticles are now known to be present in many water sources, potentially altering plant growth and food standards. Rapidly changing irrigation water quality requires more attention to understand and predict long-term impacts [11]. The sustainability of agriculture now depends on the quality of the irrigation water used. The electrolyte concentration (EC) of irrigation water can cause salt accumulation in the root zone layers and affect plant physiological functions through osmotic and ion toxicity effects [12]. There is increasing evidence of the contribution of irrigation water to product contamination which then leads to outbreaks of foodborne illnesses. One of the special risk cases occurs in the production of vegetables, especially those that will be eaten raw without cooking [13].

The quality of irrigation water taken from surface water sources varies greatly. This especially applies to waters that frequently experience contamination, such as rainwater runoff or direct entry of livestock waste into rivers. Pollution in irrigation systems increases the risk of contamination of food crops and requires the implementation of best monitoring practices [14]. The most significant and easily identified irrigation water quality parameters can be grouped into three quality classes. These three groups are based on their influence on crop yields and soil fertility (agronomic quality indicators), human health (hygiene and health quality indicators), and irrigation systems (management quality) [15].

Removal of toxic organic and inorganic pollutants from water is essential for creating a clean environment, as a response to water scarcity, and for human society. Adsorption-based water technologies are among the most preferred and widely used because of their high efficiency at low cost, without relying on complex infrastructure [16]. Water pollution is not only one of the main risk factors for illness, disease, and death but also contributes to the reduction in the availability of drinking water worldwide [17]. The local wisdom of indigenous peoples in nature conservation plays an important role in protecting the earth's biodiversity and the health of the ecosystem as a whole. However, at the same time, indigenous peoples and their lands face major threats due to modernization and globalization [18].

Farmers who are members of Subak Sembung Denpasar, in fact, from the past until now still practice local wisdom in the form of the andongan tech-

nique as an effort to purify irrigation water. The problem is that not all farmers practice the andongan concept. Meanwhile, the quality of irrigation water is decreasing due to the influx of household and industrial waste into irrigation canals. This research aims to document the local wisdom of water purification through the andongan concept in Subak Sembung, Denpasar, and understand the role of andongan in maintaining water quality in Subak Sembung. Specifically, this research aims to identify the types of plants used in andongan and their function in water purification. Another aim is to analyze the water purification process through andongan.

Samples and research methods

The research was conducted in the Subak Sembung area, Denpasar, Bali from February to May 2024. The Subak Sembung area was chosen as the focus of the research because this area has developed and been designated as an eco-tourism area located in the center of Denpasar City. Subak Sembung, as a Subak area that has become a tourist destination, also still preserves the concepts of local Balinese wisdom which are in line with sustainable agricultural development. Wiguna et al.[19] are of the view that Subak Sembung is one of the Subak that preserves nature. Subak Sembung is an urban area in Denpasar City that continues to be under pressure from tourism interests. Subak Sembung is also the hope of the city of Denpasar as a guardian of the green belt area and a large water catchment area.



Fig. 1. Subak Sembung research location, Denpasar

Subak Sembung has been one of the Subaks designated as an ecotourism area in Denpasar City, Bali since 2014. Subak Sembung Ecotourism is located in Peguyangan Village, North Denpasar District, Denpasar City with an area of

Subak reaching 115 ha and with several members of around 192 people [19]. The Denpasar City Government has made policies that support agricultural development, namely policies in terms of improving agricultural services by designating Subak Sembung as an ecotourism area. Ecotourism in question is a concept of sustainable tourism development that aims to support environmental conservation efforts [20]. The designation of Subak Sembung as an ecotourism area has caused several parties to encourage farmers in Subak Sembung to develop organic rice cultivation. Organic-based agriculture is also a form of the green revolution as a form of improving planting systems and maintaining sustainable agriculture [21].

Methodologically, this research uses qualitative methods with the hope that it will be able to explore and formulate the concept of andongan and its relationship to efforts to purify irrigation water to improve the quality and quantity of agricultural products. The qualitative method with a case study approach was chosen to explore information in more depth. This is in line with the definition of a case study as a research approach used to produce an in-depth understanding of a contemporary issue or phenomenon within a limited system [22]. The case study method identifies holistic and meaningful characteristics of real-life events. In case studies, theoretical generalizations are possible but not statistical generalizations [23]. This condition causes the case study approach to often be criticized for being too specific, not generalizable, and limited in its contribution to theory [24].

The research instrument uses the principle that the researcher is the main research instrument (human instrument). During data collection, several data collection tools were used, including draft questions for interviews, observation guidelines, and documentation sheets. Based on the human instrument principle, the types of data in this research are words, actions, situations, and events, as well as documents that can be observed. According to Takahashi & Araujo [25], the case study approach does not bind researchers to specific data collection or interpretation methods. Case study research allows for many possibilities, and should be celebrated for its diversity rather than just considering the research method to be monolithic. Qualitative case studies allow researchers to conduct an in-depth exploration of complex phenomena in several specific contexts [26].

The data processing and analysis techniques in this research were carried out qualitatively, grouping and classifying the data thoroughly based on logical connections, then interpreted in the overall research context. Researchers in this activity will try to bring out the meaning of each existing data so that it is not only descriptive but also touches on the transcendent dimension.

Research results and discussion

Andongan as Local Wisdom

Andongan for farmers in Subak Sembung, Denpasar is nothing new, because its application and use have been carried out for generations. Continuous implementation has resulted in andongan still being implemented today. This condition is in line with the basic concept of local wisdom as a legacy from generation to generation that is not eroded by various external cultural elements. Learning local wisdom is an inevitable need [27]. Another view defines local wisdom as ideas, views, or values held by a community in a place that is wise and good and that is shared by the entire community [28]. Ecological awareness is very important for communities in managing natural resource potential for the development of local wisdom [29].

Local wisdom values contain the noble values of the nation's ancestors which can be used as capital to build a nation with good and strong character [30]. Some communities still adhere to generations-old traditions of managing natural resources wisely. The application of local wisdom values needs to be taught so that future generations will better appreciate the local culture and potential that exists in the region [31]. Learning local wisdom and developing local wisdom is a step for the next generation to prove themselves so that the elders are aware of the responsibility for this learning [32].

Learning regarding the function and role of andongan is carried out in practice directly from farmers to their children or the next generation. The learning process is not carried out through providing theory but is a field learning process. This is in line with the views of Zulfadrim et al. [33] who stated that local wisdom is a system of knowledge obtained from a long process of experience in the past, adopted and passed on to the next generation through an evolutionary process. Chaer et al. [34] stated that local knowledge will only survive if local learning is applied concretely in everyday life. Efforts to represent the concept of education are not just normative; they only state and explain, but attempt a performative form. Education not only teaches concepts but also forms attitudes and character to preserve local culture. Knowledge of local wisdom is a means to achieve the goal of better understanding and loving culture [35].

Andongan is a form of Balinese wisdom in managing and treating water. Water is seen as a source of life to produce food and keep the agricultural sector sustainable. Some literature states that Balinese people respect water as part of nature which must be preserved [36]. Water is a source of life on the surface of the earth because it is a need for every organism. The need for water contin-

ues to increase, but the availability of clean water continues to decrease [10]. Conservation efforts carried out by Balinese people to extend the life of the environment through manipulating the ecology of the built environment have existed since pre-Hindu times. This effort is carried out through the community's socio-cultural belief system, and by glorifying mountains as the center of natural power that provides fertility [37].

Andongan is not only Bali's cultural heritage but also a sustainable solution for preserving water. This system is environmentally friendly and easy to maintain. Andongan is an inspiration for the development of effective and sustainable water management technology. The glorification of water, as an important component of farming life in Bali, has been mentioned explicitly in traditional texts. The Manawa Dharmaśastra, Canakya Nitisastra, Artha Śāstra, and Śarasamuccaya texts state that it is important to make every effort to preserve water so that life can survive forever. Facts on the ground show that the quality of the water used to irrigate wet rice fields is inadequate because it has been polluted by various types of waste [38]. For the Balinese people, water is a symbol of Vishnu, who is a manifestation of God as the preserver of life in the world. Positioning water as something sacred means an obligation to maintain the quality and quantity of water [10].

Andongan as an Implementation of Phytoremediation Innovation

Conceptually, the andongan is in the form of a shallow pond containing water plants such as Water Hyacinth (*Eichornia Crassipes*) and Lotus (*Nymphae sp.*) whose function is to improve water quality before it is used to irrigate rice fields. Andongan is usually made by farmers at the water inlet before it flows into the rice fields. The local wisdom of Andongan, if linked to innovation in water purification with plants, is the same as phytoremediation technology. This follows the meaning of phytoremediation which is defined as an effective, environmentally friendly, and economical technique. Various types of phytoremediation methods can be used to reduce heavy metal contamination, such as phytoextraction, phytovolatilization, phytostabilization, and phytofiltration [39]. These methods are efficient, environmentally friendly, and economical [40].

Phytoremediation is a realistic and promising strategy to remove heavy metals from polluted areas, based on the use of hyper-accumulator plant species that are highly tolerant to heavy metals present in the environment or soil. Green plants are used to remove, decompose, or detoxify harmful metals in this technique [41]. Phytoremediation has become a concern since the last decade, as a new, cheaper technology [42]. The success of the phytoremediation

process is known from several physical-chemical water parameters and several diatom biotic indices as well as the Shannon Wiener diversity index obtained from artificial substrates [43].



Fig. 2. Condition of carriages in Subak Sembung, Denpasar

The sizes of the andongan ponds in Subak Sembung vary greatly, and the size of the andongan ponds in their construction is based on the area of land that will be irrigated. The size of the carriage is between 1 m x 2 m to 2 m x 6 m, with an average depth of between 10-15 cm. The size of the andongan does not seem to have much influence on the quality of water purification, but in each andongan the types of plants used are generally the same. This is in line with the opinion of Jia et al. [44] which states that plant species are the main factor that drives variations in removal efficiency in phytoremediation. Plant species can influence the colonization pattern and metabolic activity of inoculated endophytic bacteria and ultimately influence the phytoremediation process [45]. Plants primarily use their metabolism including interactions with microorganisms to improve their ecological environment. In the remediation process, plant purification factors are influenced by many conditions such as light intensity, stomatal conductance, temperature, and microbial species [46]. Important practical considerations in implementing aquatic phytoremediation include the use of invasive species, optimal timing and frequency of harvesting to remove pollutants with macrophyte biomass, and the full role of microbial biofilms in phytoremediation [47].

During phytoremediation, plants can transport trace elements and bind them in their cell walls, chelate them in the soil in an inactive form using secreted organic compounds, or complex them in tissues after transporting them into specialized cells and cell compartments [48]. The efficiency of phytoremedi-

ation depends on several factors including metal bioavailability and plant uptake, translocation, and tolerance mechanisms [49]. Many factors influence the selection of a suitable phytoremediation strategy for soil decontamination. This depends on soil properties, levels and characteristics of heavy metals, plant species, and climatic conditions [50]. Aquatic phytoremediation is a nature-based solution that has the potential to provide efficient, spatially adaptable, and multi-target treatment of polluted waters by using the ability of macrophytes to absorb, adsorb and degrade pollutants [47].



Fig. 3. One of the large carriages (1.5 m x 5 m) in Subak Sembung

Identification of Water Purification Plants in the Implementation of Andongan

There are 2 types of plants used in andongan, namely water hyacinth (*Eichornia Crassipes*) and lotus (*Nymphaeae sp.*). The choice of these two types of plants is also related to their use in the daily lives of farmers in Subak Sembung. When the water hyacinth is large and lush, it can be harvested to be used as feed for ducks and pigs. Water hyacinth in Sri Lanka has for decades been used as feed for ruminants, pigs, ducks, geese, and fish because of its high crude protein content and progressive growth [51]. The amino acid profile of water hyacinth makes it suitable for use as feed pigs. When water hyacinth is used as poultry feed, it increases egg laying ratio and improves cellular immunity of birds [52].

The selection of water hyacinth as a plant in the carriage is based on the knowledge obtained from generation to generation by farmers from their predecessors. Based on the knowledge and experience gained, farmers believe that water hyacinths can improve water quality. This knowledge of farmers in Subak Sembung is in line with several research results that state that water hyacinth can be used to purify water [53]. Water hyacinth is a macrophyte that has the potential to remove ammonia nitrogen [54]. Ammonia appears to be the water hyacinth's preferred nitrogen source. Water hyacinth can survive bad weather conditions below 5 °C for a short time [53].

The ability to adapt to various environmental conditions and high nutrient absorption capacity means water hyacinth has a broad contribution to phytoremediation purposes [54]. Nitrate in agricultural eutrophic wastewater can be utilized by water hyacinth as nitrogen nutrition and can promote plant growth by using soluble sugars and urea to synthesize amino acids and proteins [55]. Water hyacinth has a biosorption capacity in reducing the concentration of dyes, and heavy metals and minimizing certain other physiochemical parameters such as TSS (total solid suspension), TDS (total dissolved solids), COD (chemical oxygen demand) and BOD (biological oxygen demand) in textile wastewater [56].

The flowers on the andongan are usually used by farmers for religious ceremonies. The lotus is seen as a sacred flower with many virtues that other plant flowers generally do not have. Lotus in general, has a living habitat in three realms; namely land (lower realm), water (middle realm), and air (upper realm). A lotus flower that blooms perfectly seems to be able to separate itself from all the dirt in its place of life. A study revealed that the lotus flower has great religious and cultural significance, revered for its characteristic of being able to rise above muddy water, which shows how one can overcome the inner defilements of life. Apart from being a motivation for life, this plant also provides fiber which is used to make rare types of fabric that match the perfect quality of silk [57].

The lotus flower is one of the most famous plants in ancient Egyptian civilization because of its connection with religion and the daily life of ancient Egyptian society [58]. Lotuses are highly valued for their decorative, economic, and cultural uses [59]. This fragrant flower with white, blue, and red colors, and as a sacred symbol in the life of the ancient Egyptians was not only an aesthetic decorative component depicted by the ancient Egyptians on the walls of temples, or used in making perfume. And cosmetics, but also used in the decoration of palaces, houses, and tombs in certain decorative forms [58].

The use of lotus as part of the carriage was obtained by farmers from the knowledge gained from generation to generation. This farmer's knowledge is

in line with research results which state that lotus flowers are naturally occurring superhydrophobic. Superhydrophobicity is evolutionarily adaptive to the surrounding environment. Self-cleaning agents function effectively on superhydrophobic surfaces so that water droplets rise and fall from the surface thereby removing contamination particles [60].

Lotus plants are hyperaccumulators because they can significantly reduce the load of physicochemical pollutants and heavy metals in industrial waste. The heavy metal content in lotus roots is generally higher than in plant leaves [61]. Lotus can act as a hyperaccumulator of Lead (Pb), thereby reducing the danger of metal pollution in water ecosystems and decontaminating fresh water [62]. Lotus plants are also able to remove organic contaminants from surface water by supplying O₂ gas at 0.2–2.1 ml/minute [63]. Based on experiments, lotus was able to reduce COD by 32.91 %, reduce BOD levels by 31.54 %, reduce phosphate levels by 3.55 %, and reduce nitrate by 19.61 % [64]. This causes the Lotus plant to provide a sustainable approach towards effective biotreatment of mixed hazardous waste using plant-based environmentally friendly technology [61].

Sustainability of Implementation of Andongan Innovation

Andongan, as a phytoremediation concept that has existed since ancient times, has great potential for cleaning contaminated soil and water. However, its sustainable implementation still faces several challenges. Based on the results of an interview with the Chairman of Subak Sembung, I Made Darayasa, the biggest challenge in preserving andongan lies in the farmer's decision. There is a tendency that sharecroppers are reluctant to make carriages because it will reduce the planting area which will then have an impact on production or crop yields. Where around 40% of farmers in Subak Sembung are sharecroppers and 60 % are farmers who are also landowners. This is in line with the view of Tesfahunegn [65] who states that socioeconomic and biophysical factors determine farmers' views on efforts to preserve the environment. The main cognitive driving factors that influence farmers' attitudes include increasing crop yields, reducing labor, improving soil quality, and reducing weeds [66]. Unsustainable production systems can exacerbate negative impacts and changes in land use, thereby increasing the vulnerability of local populations to environmental and economic crises [67].

The next challenge in preserving andongan is the limited number of farmers who farm in an integrated manner while raising ducks, cows, and pigs. The impact is that farmers no longer cultivate water hyacinths to use as animal feed. This condition is in line with farmers around Lake Mutirikwi, Masvingo, Zimbabwe, where the perceptions and attitudes of farmers who have small livestock

and do not have livestock tend to dislike and do not use water hyacinth plants [68]. Water hyacinth tends to be considered an aquatic invasive weed because people do not know how to use it, such as using it for sustainable wastewater management [69]. Water hyacinth is an ancient technology that is still used today. Water hyacinth has been proven to be suitable for controlling various types of wastewater originating from urban and industrial areas [70].

The next challenge is that young farmers in Subak Sembung still don't know enough about andongan and its benefits in environmental remediation. Limited information about andongan causes reluctance to implement it. The same condition occurs in various countries, although research on phytoremediation technology is seen as a potentially useful contribution to more sustainable remediation, in fact this practice is still rarely implemented in remediation practices in European countries [71]. Phytoremediation is underutilized despite its proven success and potential. Commercial phytoremediation technologies appear to be underutilized globally [72]. Phytoremediation provides an approach that requires minimal costs and environmental impact. Integrating phytoremediation with other profitable activities including food production can be an alternative to optimize the implementation of phytoremediation [73].

Conclusion

Andongan as a local wisdom from Subak in Bali has a function as a water purifier by using plants as water purifiers. An andongan concept is a form of implementation of phytoremediation technology that has been carried out by Subak farmers in Bali for generations. Andongan is part of integrated farming with animal husbandry, where farmers dispose of andongan as part of efforts to purify water and as part of providing feed for pigs and ducks.

Two types of plants are very commonly used in making andongan, namely water hyacinth (*Eichornia Crassipes*) and lotus (*Nymphaeae sp.*). When the water hyacinth grows in thousands, it is used by farmers as feed for ducks and pigs. The lotus was chosen in the Andongan because the flowers are used for religious ceremonies. Sometimes farmers also sell the lotus flowers they produce, because of the high demand for lotus flowers during religious ceremonies in Bali.

The challenge in sustaining the andongan concept in Subak is currently hampered by the land ownership status of farmers. Cultivator farmers tend to be reluctant to make carriages because they think it will reduce the production area which will have an impact on reducing production. Another challenge is that farmers are increasingly integrating agriculture with animal husbandry so that hyacinth production is no longer used as feed for ducks or pigs.

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