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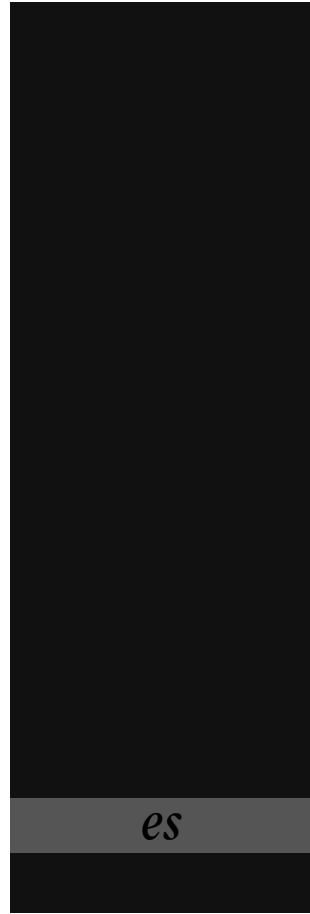
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# Treatment Ability and Community Responses of Candung as an Appropriate Technology to Maintain Irrigation Water Quality

## Keywords

Candung, constructed wetland, irrigation water, *Nelumbo nucifera*, *Nymphaea tetragona*, *Pistia stratiotes*, agrotourism

## Abstract

With the burgeoning population, the community activities have expanded along the irrigation canal, such as laundering, washing, or even bathing. Consequently, some chemical from those activities is released and pollute the water body. Besides, the discharge of wastewater into the irrigation system is also an issue of public health concern because it creates an environment conducive to the reproduction of any pathogenic agent. Using Candung as constructed wetlands (CW)-like to treat the irrigation water in rice paddies would be an interesting tool for removing pollutants from the irrigation water. Candung as a locally CW in Bali Island has been applied in the rice field long time ago. The present study aims to examine Candung as a local attached CW or treating irrigation water and analyzing the community awareness regarding the Candung application. The result showed a positive effect of Candung in maintaining the water quality parameters, such as TSS, BOD, COD, and nutrients with certain aquatic plants (*Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*). The knowledge, behaviour, and action of the local Subak community were still limited, whereas they had positive perceptions and responses about Candung's potential as an agrotourism attraction in the village as well.

## Treatment Ability and Community Responses of Candung as an Appropriate Technology to Maintain Irrigation Water Quality

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### ABSTRACT

With the burgeoning population, the community activities have expanded along the irrigation canal, such as laundering, washing, or even bathing. Consequently, some chemical from those activities is released and pollute the water body. Besides, the discharge of wastewater into the irrigation system is also an issue of public health concern because it creates an environment conducive to the reproduction of any pathogenic agent. Using Candung as constructed wetlands (CW)-like to treat the irrigation water in rice paddies would be an interesting tool for removing pollutants from the irrigation water. Candung as a locally CW in Bali Island has been applied in the rice field long time ago. The present study aims to examine Candung as a local attached CW or treating irrigation water and analyzing the community awareness regarding the Candung application. The result showed a positive effect of Candung in maintaining the water quality parameters, such as TSS, BOD, COD, and nutrients with certain aquatic plants (*Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*). The knowledge, behaviour, and action of the local Subak community were still limited, whereas they had positive perceptions and responses about Candung's potential as an agrotourism attraction in the village as well.

**Keywords:** Candung, constructed wetland, irrigation water, *Nelumbo nucifera*, *Nymphaea tetragona*, *Pistia stratiotes*, agrotourism

## 1. INTRODUCTION

The irrigation water in villages in tropical countries is facing a reduction in water quality. It urgently needs to be concerned, so it can be effectively utilized as irrigation water for agriculture, aquaculture and potentially even household needs [1]. The rapid changes in land and water use due to dynamic farming intensity is the main factor affecting water quality and quantity, ecology, and biodiversity globally [2]. The community activities have expanded along the irrigation canal, such as laundering, washing or even bathing. Solid waste is also dumped in the channel and causes floods during the rainy season because clogged with plastics. The type of pollutants within domestic wastewater can significantly vary based on location and pollutant type [3,4]. Consequently, some chemical from those activities is released and pollute the water body. Besides, the discharge of wastewater into the irrigation system is also an issue of a public health concern as the dormant odour and suitable breeding of any pathogen [5,6].

The main source of agricultural irrigation water comes from surface water. Due to the spatial difference in water content in wetlands, streams and rivers, assessment is necessary to provide robust insights into the quality and quantity of water that enter the paddy fields [2,7]. Human activities around the paddy fields are influencing the nutrient input in the irrigation system, which leads to water physicochemical conditions. The trophic state is defined by the factors that are related to nutrient contents, algae biomass and water transparency [8]. It causes water quality deterioration due to the discharge of untreated wastewater from the municipality [9,10].

Therefore, a pre-treatment is urgently needed before the irrigation water enters the paddy fields, using natural depollution process such as the constructed wetland. Agricultural practices have been developed using large amounts of chemical fertilizers and pesticides to sustain yields and productivity. This practice raised the level of nutrients reaching the aquifers, therefore contaminating the surface and groundwater [11]. Constructed wetland (CW) is engineered systems that simulate

51 processes from natural wetlands. With low external energy requirements, it improves water quality by  
52 means of a combination of physical, chemical, and biological processes [12]. The last few years  
53 showed that artificial or constructed wetlands were frequently used to treat wastewater due to their  
54 low-cost operation and maintenance, low energy consumption and ease of operation [13]. It consists  
55 of vegetation, substrates, microorganism, and soil components to support the water treatment  
56 process [9,14]. Managing surface water pollution is critical for the economy, ecosystem, and human  
57 health concerns. CW can be installed in a pond that acts as a catchment area, flood controllers, and  
58 groundwater runoff. The CW has a role as trash trap and sedimentation storage so the water can be  
59 free of debris and sediment loads [15]. The present study aims to examine Candung as a local  
60 attached constructed wetland for treating irrigation water, with additional plants cultivation and  
61 analyzing the community awareness regarding the Candung application.

## 62 **2. METHODOLOGY**

### 63 **2.1 Study Location**

64 The research was conducted in a local irrigation water community named Subak Lepud. It is  
65 located in Baha Village, Badung Regency, Bali Island. It was supported by the Subak Lepud  
66 community and also farmers around the subak area. Candungs were built in the corner of each paddy  
67 fields area and connected to the irrigation water system along the paddy fields area. It is a 1 x 1-meter  
68 area bordered by higher subsoil levels in order to maintain the water overflow. Within about 50 cm of  
69 depth, Candung could receive and hold about 0,5 m<sup>3</sup> of water at a time. The solid content of irrigation  
70 water could be settled during the storage of Candung. There were three water plants used in  
71 Candung, such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*. Those plants are  
72 commonly used as decorative plants at home, in parks or gardens; meanwhile, in this research, they  
73 were used as emergent plants. The water will flow along the irrigation channel, enter Candung, which  
74 is installed in the entrance and flow to the paddy field.

### 75 **2.2 Water Quality Sampling**

76 The irrigation water samples were collected from 15-20 cm below the surface in the month  
77 of September 2021. Those were taken in Candung box, which is placed right before the irrigation

79 water enters the paddy fields. The water samples were taken at the upstream, midstream, and  
80 downstream points. Sample water was also taken from each Candung box right after those stream  
81 points. There are three Candung boxes at each point (upstream, midstream, downstream). Those  
82 Candungs represent the different water plants mentioned above. Accordingly, there are 12 water  
83 samples have been analysed in this study. The samples were preserved and analysed for physico-  
84 chemical characteristics. The total dissolved solids (TDS) and total suspended solids (TSS) were  
85 measured by using filtration and gravimetric method. The accuracy of those methods is well  
86 performed in the scientific literature [16]. A 100 mL water sample was poured into weighed glass fibre  
87 filter of a specified pore size before starting the vacuum filtration. The filter was taken up after the  
88 completion of the filtration and placed in an aluminium dish in an oven at 100°C for 2-3 hours to  
89 completely vaporize the remaining water. Afterwards, the filter paper was weighed, and the gain in  
90 filter weight showed the TSS contents in mass per volume of the filtered sample (mg/L). The TDS  
91 were determined by the gravimetric method. After filtration for TSS analysis, the filtrate was placed in  
92 the oven at above 100°C until all the water was totally evaporated. The remaining mass of the residue  
93 represents the TDS in the water sample. The chemical compound such as dissolved oxygen (DO),  
94 biological oxygen demand (BOD), chemical oxygen demand (COD), ammonium and phosphate were  
95 measured according to the standard method [17]. The samples were measured in the Laboratory of  
96 Health of Bali Province in triplicates repeat.

### 97 **2.3 Community Responses Questionnaire**

98 A community perspective has been analysed through a questionnaire with five variables,  
99 such as knowledge, behaviour, action, perception, tourism potential and health food material. The  
100 knowledge variable is interpreted as the understanding of the Subak Lepud members towards  
101 Candung and water plants on agricultural land. In this study, the knowledge variable was measured  
102 by six indicators, namely: (1) the benefits of Candung and water plants for environmental preservation;  
103 (2) the impact that occurs if Candung and water plants are not preserved; (3) the benefits of water  
104 plant species (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*) in aquatic  
105 ecosystems; (4) the impact of destroying and removing phytoremediation plant species from the

107 environment; (5) the importance of conserving water plant species as phytoremediation/toxic  
108 absorbers; and (6) procedures for the preservation of Candung and water plants.

109 The attitude variable is interpreted as the reaction of Subak Lepud members from their  
110 understanding of Candung and water plants on agricultural land. In this study, the attitude variable  
111 was measured by five indicators, namely: (1) participating in conserving Candung and water plants  
112 to maintain the balance of the ecosystem; (2) participating in conserving Candung and water plants  
113 as an environmental conservation measure; (3) participating in conserving Candung and water plants  
114 for subak irrigation which are polluted by waste; (4) taking part in maintaining the local wisdom of  
115 Candung and water plants because it can improve the ecological and economic welfare of the  
116 community; and (5) participating in conserving water plant species as phytoremediation/toxic  
117 absorbers. The action variable is defined as the actions committed by members of the Subak Lepud  
118 against Candung. In this study, the action variable was measured by five indicators, namely: (1) not  
119 creating Candung and planting water plants in Candung; (2) not making Candung and planting water  
120 plants so that the rice planting area is wider; (3) conserving Candung and water plant species because  
121 they have important ecological functions that are beneficial; (4) planting water plants in Candung  
122 (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*), because they have economic  
123 value; and (5) participating in the conservation of Candung and water plants that absorb  
124 poisons/contaminants. The perception variable is interpreted as the views of Subak Lepud members  
125 regarding the benefits of Candung on agricultural land. The perception variable is measured by five  
126 indicators, namely: (1) the sustainability of Candung and water plants can be beneficial for the balance  
127 of aquatic ecosystems; (2) the benefits of Candung and water plants in maintaining and improving  
128 water quality; (3) the benefits of Candung and water plant species for organisms that live in rice fields;  
129 (4) the benefits of preserving Candung and water plants to overcome water pollution that enters rice  
130 fields; and (5) the benefits of conserving Candung and water plants for the community.

131 The variable of the potential for educational tourist attractions is interpreted as the views of  
132 Subak Lepud members regarding the potential of Candung and water plants on agricultural land as  
133 educational tourist attractions and healthy food providers. In this study, the variable of the potential of  
134 educational tourist attractions was measured by five indicators, namely: (1) Candung and water plants



(such as *Nelumbo nucifera*, *Nymphaea tetragona*) have subak local wisdom values; (2) Candung and water plants that absorb pollutants (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*) will be able to produce healthy food products; (3) Candung and pollutant-absorbing water plants (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*) can be used as educational tourist attractions; (4) support from subak members in the conservation of Candung and water plants (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*); and (5) a district/provincial government policy is needed for the conversation of Candung and water plants as educational tourist attractions.

Inferential analysis was carried out by using Path Analysis with the help of the Smart-PLS program. The analysis was first performed to evaluate the structural model by taking into account the  $Q^2$  predictive relevance model. The goal was to measure how well the observed values were generated by the model.  $Q^2$  is based on the coefficient of determination of all dependent variables. The value of  $Q^2$  has a range of  $0 < Q^2 < 1$ , the closer to 1, the better the model. In this structural model, there are two endogenous (dependent) variables, namely: Perception, Action and Potential, so three coefficients of determination ( $R^2$ ) can be determined, which are the basis for calculating the  $Q^2$  predictive relevance model.

To obtain data that has good calibration for each of the variables studied, the research instrument needs to be tested for its validity and reliability. Based on this, it is important to carry out tests to ensure the level of validity and reliability of the research instrument is in accordance with the specified criteria. Testing the research instrument was carried out by means of a trial (pre-research) by distributing 35 questionnaires to Subak Lepud members. The validity test aims to measure whether the research instrument is valid or not. The research instrument is said to be valid if the instrument is able to accurately measure what is to be measured (Ghozali, 2009). Testing the validity of this instrument uses the validity of the criteria calculated through corrected item correlation analysis. Through this analysis, the research instrument is said to be valid if it has a correlation coefficient above 0.30. Meanwhile, the reliability test aims to measure the internal consistency of an indicator of a variable. High-reliability results provide confidence that all individual indicators are consistent with their measurements (Wijanto, 2008). This reliability test uses the one-shot method or is done only

165 once, which is measured using Cronbach Alpha ( $\alpha$ ) analysis. A variable is said to be reliable if it has  
166 a Cronbach Alpha ( $\alpha$ ) value above 0.60 (Nunally, 1960 in Ghozali, 2009). The results of testing the  
167 research instrument from the questionnaire trial ( $n = 35$  samples) that was carried out can be  
168 presented in Table 1 below

169 **Table 1.** Recapitulation of Research Instrument Testing Results

170 Information from Table 1 above shows that all statement items from five variables, namely  
171 knowledge, experience, intention, action and potential were valid (correlation coefficient was above  
172 0.30) and showed a good level of reliability (Cronbach's Alpha correlation coefficient ( $\alpha$ ) was above  
173 0.60). Thus, the research instrument (questionnaire) could be used and distributed to all  
174 predetermined target samples. The data collected was 182 units out of 200 units which were  
175 distributed to all members of Subak Lepud. The results of the further examination showed that the  
176 182 data units had been filled in completely, so they were ready for further analysis.

### 177 **3. RESULTS AND DISCUSSION**

#### 178 **3.1 Candung as a Locally Appropriate Technology**

179 The silt that may be drifted along the irrigation system needs to be removed in a sedimentation  
180 chamber before entering the paddy fields. This Candung will help reduce the clogging irrigation  
181 system and eliminate a large part of the particulate organic load and forms of nutrients entering ponds.  
182 The Candung pool is shallow and sealed around to maintain the overflow. Soil is the main substrate  
183 of Candung and covers up to 50 cm thick and thus, allowing the formation of wetland plants [9].  
184 According to Kadlec [18], there are four main principles of constructed wetlands, including Candung.  
185 They are balancing the conversion rate of natural wetlands resulting from agriculture and urban  
186 development, improving the water quality after the treatment, flood control and supporting food  
187 production. Candung can be considered as part of the wastewater treatment system to provide  
188 physical and biological treatment. Vegetation, substrates, soils, microbes, and water are the essential  
189 components of the technique. To remove various contaminants, it employs complex processes

191 involving physical, chemical, and biological mechanisms [9]. The wastewater treatment in Candung  
192 is commonly practiced through biological processes (like microbial activity and plant uptake) and  
193 physicochemical processes (like precipitation, adsorption, and sedimentation) [19]. As a system,  
194 Candung belongs to a free water surface constructed wetland (FWSF) which operates like a natural  
195 wetland. One of the important parts of Candung is the emergent plants which have several purposes  
196 and be mutual with the microorganism. The stems and submerged leaves are supporting the growth  
197 of bacteria, and the leaves above the surface shade the water and reduce the potential for rapid algae  
198 growth, and oxygen from the atmosphere is transported from the leaves down to the roots, which  
199 support the plant growth.

200 Constructed wetlands (CWs) for wastewater treatment are a natural, simple, low construction  
201 and maintenance cost, and environmentally friendly method, representing alternative and promising  
202 solutions for environmental protection and preservation. CWs are most suitable for small areas and  
203 rural communities [20]. Water and nutrient recycling are emerging and part of water management.  
204 Proper wastewater treatment is an issue in sustainable development related to water demand and  
205 designed due to growing populations, whereas global climatic changes have increased water stress  
206 conditions, especially in limited water resource areas [21]. In constructed wetland systems, plants can  
207 play an important role in the removal of nutrients from wastewater compared to unplanted wetlands.  
208 Macrophytes can improve wastewater quality by helping to settle suspended solids, directly uptake  
209 nutrients, and provide support for microbial flora [22].

210 Therefore, the seasonal selection of plants for constructed wetlands should be an important part  
211 of wastewater treatment management in a CW system. Most of the previous research on constructed  
212 wetlands covered one plant season, but the period of vegetative growth followed, culminating in death.  
213 After completion of a life cycle, plants leave, roots begin to die, and if plants remain in the CW, decay  
214 from the plant material will release nutrients back to the CW. Therefore, appropriate plants for the  
215 specific season will optimize the function of the constructed wetland.

## 3.2 Treatment Ability of Candung

### 3.2.1 pH, Total Suspended Solid (TSS), and Total Dissolved Solid (TDS)

pH is one of the important water quality characteristics that represent the acidity or alkalinity of the water sample. A pH below 7.0 is considered acid, while an alkaline is if the pH is above 7.0 (Sawyer et al., 2003). The hydrogen-ion concentration is very important to speed up the biochemical process, which is also depending on the current enzyme. The enzyme sometimes needs a certain pH value to get the best reaction rather than a lower pH or higher pH. The pH affects the suitability of available water to support the living organism (Qasim, 1999; Tchobanoglous et al., 2002). Acidic water can affect the corrosion of metal; meanwhile, alkaline is presenting disinfection of the water. The normal drinking water pH range is around 6,5-8,5 (World Health Organisation (WHO), 2017). The pH in the 12 water samples showed a pH range between 7,0-8,0. The lowest pH was found at the upstream point with 7,39; meanwhile, the highest one was found at the downstream point after the Candung with *Nymphaea tetragona*. According to the pH analysis, the pH value from the upstream to the downstream increased from 7,39 to 7,88.

After passing through the Candung, there were some changes to the pH value. After the upstream, the pH value of the effluent of Candung with *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes* was 7,42; 7,64; 7,43, respectively. In the mid-stream, the pH was measured at 7,71; 7,75; 7,71, respectively, for three Candungs; meanwhile, the downstream were 7,93; 7,81; and 7,79. All the pH values of those effluents were covered by the national pH threshold of 6-9. According to Amic and Tadic (Amić & Tadić, 2018), the pH value of various stream water environments is in the range of 6,5 to 8,5, while pH below 4 (acid) and above 10 (base) creates a damaging living environment.

**Figure 1.** The pH value in each effluent of Candung from upstream (1), mid-stream (2) and downstream (3)

242 The presence of various solid particles, whether suspended or dissolved, is characterized by  
243 the physical water quality (Soedjono et al., 2018; Wijaya & Soedjono, 2018). The solid shows the  
244 amount of particle or slurry left when the water is totally removed. The total solid is the content of solid  
245 in a sample after the sample has been dried at over 100°C for 24 hours and compared to the original  
246 mass of the sample. Total dissolved solids (TDS) is the sample that only can appear in dry conditions,  
247 while total suspended solids (TSS) still remain intact when put into the water (Hamilton & Zhang,  
248 2003; Ramesh & Jain, 2017). Total solid is represented by the sum of TDS and TSS. Water with a  
249 high dissolved solid concentration has an adverse impact on irrigation crops and plants; meanwhile,  
250 the highly suspended solid can cause a scum layer (floating solid) or build-up sediment (sink solid)  
251 (Ayoade et al., 2019; M. Faisal et al., 2015). The limit of TSS and TDS according to the national water  
252 quality standard for class II are 50 mg/L and 1000 mg/L, respectively. The TSS concentration  
253 increased from the upstream to the downstream due to the wastewater discharged along the stream.

254 The TSS measurement showed various changes in the TSS concentration in the effluents  
255 after passing through Candung. At the upstream point, the TSS of effluent increased after Candung  
256 with *Nelumbo nucifera* and *Pistia stratiotes* with 85 mg/L and 59 mg/L, respectively. There was no  
257 change of TSS after Candung with *Nymphaea tetragona* at 39 mg/L. TSS contributes to the sediment  
258 in the water body and potentially causes oxygen depletion. It is important to control the treatment  
259 process following the effluent regulation (Hudson, 2010; Wijaya et al., 2019). According to the national  
260 water quality standard classification (*Peraturan Pemerintah Republik Indonesia Nomor 82 Tahun*  
261 *2001 Tentang Pengelolaan Kualitas Air Dan Pengendalian Pencemaran Air*, 2001), those  
262 concentrations were out of Class II water quality and belonged to Class III. The effluent TSS from  
263 Candung at the mid-stream and downstream has declined for all plants. The decreasing TSS indicates  
264 that the plants have promoted the solid to settle down as sediment. The highest removal of TSS was  
265 found in the mid-stream and downstream's Candung for *Nelumbo nucifera* (60,34%) and *Pistia*  
266 *stratiotes* (63,75%), respectively. TSS concentration from the upstream, midstream, and downstream  
267 can be seen in **Figure 2** below.

268 Total dissolved solids (TDS) indicate the dissolved salt in the water sample out of the  
269 suspended solid (SS). The TDS concentration is related to electrical conductivity or conductance. It

271 shows the ability of water to transmit an electrical current that increases as the TDS concentration  
272 increases (Larrarte & Pons, 2011; Ramesh & Jain, 2017). TDS consists of various inorganic salts,  
273 such as sodium (Na<sup>+</sup>), calcium (Ca<sup>+</sup>), magnesium (Mg<sup>+</sup>), potassium (K<sup>+</sup>), chloride (Cl<sup>-</sup>), nitrates (NO<sup>3-</sup>  
274 ), and bicarbonates (HCO<sup>3-</sup>). According to World Health Organization (WHO) standard for water  
275 quality, the permissible TDS for agriculture is in the range of 450-2000 mg/L (Jamei et al., 2020). In a  
276 stream and rivers, the conductivity capacity is altered by various factors, such as soil type, rock type,  
277 and the presence of dissolved solids (Vadde et al., 2018). TDS consists of ionic constituents that  
278 conduct electricity. TDS and bulk conductivities of sediment in the water body are generally higher at  
279 contaminated locations (Atekwana et al., 2004). Water with high TDS has been known to cause a  
280 detrimental effect on organism health due to its adverse effect on feedstock (Sharma et al., 2017). A  
281 study from Devesa and Dietrich (Devesa & Dietrich, 2018) stated that the TDS also could represent  
282 the mineral content in the water body and affect the taste of the water. It can be considered with a  
283 concentration of TDS>150 mg/L. The TDS analysis in this study showed that the TDS concentration  
284 was very low under the national water quality standard classification (*Peraturan Pemerintah Republik*  
285 *Indonesia Nomor 82 Tahun 2001 Tentang Pengelolaan Kualitas Air Dan Pengendalian Pencemaran*  
286 *Air, 2001*), which is 1000 mg/L.

287 **Figure 2.** The TSS concentration in each effluent of Candung from upstream (1), mid-stream (2) and  
288 downstream (3)

289 TDS in the upstream point was measured at 138,9 mg/L, while in the mid-stream and  
290 downstream was 133 mg/L and 127 mg/L, respectively. Candung has no significant effect on the TDS  
291 concentration after the water passes it through. The lowest TDS concentration from the Candung was  
292 found at the mid-stream point after Candung with *Nymphaea tetragona*, which was 119,5 mg/L. A low  
293 TDS is also found in the study by Masood et al. (Masood et al., 2023), which is in a range of 99,6-  
294 101,2 mg/L with a standard value in the range of 400-500 mg/L. The decline of TDS concentration  
295 after all Candungs is presented below in **Figure 3**.

297 **Figure 3.** The TDS concentration in each effluent of Candung from upstream (1), mid-stream (2) and  
298 downstream (3)

### 299 **3.2.2 Biological Oxygen Demand (BOD)**

300 An enormous BOD concentration in the water body damages the water quality. It causes a  
301 low dissolved oxygen (DO) condition and an unfavourable life environment for the aquatic organism.  
302 BOD and DO have an exchange relationship with the riverbed, nitrification and denitrification (Koklu,  
303 2009). BOD represents the total oxygen consumption to break down the organic material, which is  
304 performed by aerobic biological microorganisms (G. H. Faisal et al., 2020; Gu et al., 2013). It provides  
305 information about available biodegradable fraction which is loaded in the water (Jouanneau et al.,  
306 2013). The decrease in BOD is possibly caused by the oxidation of organic matter, which provides  
307 the energy resource for the microorganism metabolic process and is synthesized into cell mass  
308 (Marcato et al., n.d.). BOD is a commonly used parameter for assessing the biodegradability of  
309 dissolved organic matter in the water body (Simon et al., 2011).

310 **Figure 4.** The BOD concentration in each effluent of Candung from upstream (1), mid-stream (2) and  
311 downstream (3)

312 The aerobic microbiological degradation and sedimentation/filtration processes are the  
313 primary causes of BOD decrease. In subsurface flow wetlands, organic molecules can be destroyed  
314 both aerobically and anaerobically. Atmospheric oxygen diffusion, convection (wind effect), and/or  
315 macrophyte root transfer into the plant rhizosphere can provide oxygen for aerobic breakdown.  
316 Without oxygen, anaerobic organic elimination might take place inside the media pores. Anaerobic  
317 degradation is a two-step process undertaken by anaerobic heterotrophic bacteria in wetlands. Acid-  
318 forming bacteria synthesize organic materials into new cells, organic acids, and alcohols in the first  
319 phase (fermentation). Methane-forming bacteria, in the second stage, continue the oxidation  
320 (methanogenesis) by turning organic molecules into new bacterial cells, methane, and carbon dioxide.  
321 In the anaerobic zones of wetlands, fermentation and methanogenesis occur (Abedi & Mojiri, 2019;

323 Kadlec & Wallace, 2008). The BOD concentration since the upstream is in the range of 1-5 mg/L  
324 (Figure 4), which belongs to the water class I-III according to the national water quality standard (PP  
325 No.8/2001). The BOD was classified as low BOD concentration in all streams. In the upstream, the  
326 BOD was measured at 1,61 mg/L; in the midstream was 1,21 mg/L and in the downstream was 1,11  
327 mg/L. The BOD decreased from the upstream to the downstream, which indicates the removal along  
328 the stream. The role of water plants has shown the changes of BOD in the stream water. The lowest  
329 BOD concentration was found in Candung upstream area with *Pistia stratiotes* with 1,21 mg/L. In the  
330 midstream, the BOD was found to increase to 1,81mg/L in Candung with *Nelumbo nucifera*, and in  
331 the downstream, there were significant changes of the BOD in Candung with *Pistia stratiotes* with  
332 5,13 mg/L. The increase in BOD indicates that more dissolved oxygen in the stream is depleted. It  
333 could be caused by the settlement of debris, leaves, woods, dead plants and animal that becomes  
334 biomass and carbon sources.

### 335 **3.2.3 Chemical Oxygen Demand (COD)**

336 COD is described as the number of oxygen equivalents used in oxidizing the organic matter  
337 of samples by strong oxidizer agents such as dichromate or permanganate. The higher the chemical  
338 oxygen demand, the higher the concentration of pollution in the water sample (G. H. Faisal et al.,  
339 2020). COD is considered one of the most important water quality parameters of wastewater. The  
340 typical BOD/COD ratio for untreated household wastewater is 0.3–0.8; a BOD/COD ratio of 0.5 or  
341 above indicates that the available organics are easily degradable by microbes, whilst a ratio below  
342 0.3 indicates that the available organics are harder to breakdown by microorganisms (Kadlec &  
343 Wallace, 2008). According to the results of COD concentration after passing through each Candung,  
344 the effluent of Candung at the upstream and downstream gave negative results or significantly  
345 increased the COD. The BOD/COD ratio was found very low in all water sources (upstream, middle  
346 stream and downstream), below the threshold value to provide a proper environment for the  
347 microorganism, which is at least 0,5 or above. It results in low organic removal percentages because  
348 of the decrease in microbial activities to degrade the organic matter. A low BOD/COD ratio gives more  
349 insight into the COD concentration, whereas the organic matter that has to be degraded with chemical



351 oxidants, such as potassium dichromate, is higher than the biodegradable (BOD). Besides, the  
352 presence of humic material in *Candung* also contributes to the higher COD concentration. Humic  
353 substances contain carbon, hydrogen, oxygen, nitrogen and small amounts of sulphur and  
354 phosphorus. Humic substances contained in products are commonly used in agriculture as part of the  
355 fertilizer, but on the other side, their rise is also a sign of organic pollutant levels, colour intensity, and  
356 chemical activities in the water (Rupiasih, 2016).

357 **Figure 5.** The COD concentration in each effluent of Candung from upstream (1), mid-stream (2) and  
358 downstream (3)

359 **Table 2.** The BOD/COD ratio of each stream and candung

### 360 **3.2.4 Nutrient Content**

361 The most important organic forms of nitrogen in constructed wetlands are ammonium ( $\text{NH}_4^+$ ),  
362 nitrite ( $\text{NO}_2^-$ ), and nitrate ( $\text{NO}_3^-$ ). Gaseous nitrogen can be present as dinitrogen ( $\text{N}_2$ ), nitrous oxide  
363 ( $\text{N}_2\text{O}$ ), nitrous oxide ( $\text{NO}_2$  and  $\text{N}_2\text{O}_4$ ), and ammonia ( $\text{NH}_3$ ). Various forms of nitrogen are always  
364 involved in the chemical conversion of inorganic compounds to organic compounds and from organic  
365 compounds to inorganic compounds (Abba et al., 2021). Some of these processes require energy  
366 (usually from an organic carbon source) to continue, while others release the energy that the organism  
367 uses for growth and survival. All of these transformations are necessary for the normal functioning of  
368 wetland ecosystems, and most chemical changes are facilitated by the production of enzymes and  
369 catalysts by organisms that benefit them (Vymazal, 2007). Ammonia is converted from its organic  
370 form through a complex, energy-releasing, multi-step biochemical process. In some cases, this  
371 energy is used by the microorganisms for growth and ammonia is incorporated directly into the  
372 microbial biomass. Nitrogen assimilation refers to various biological processes that convert inorganic  
373 forms of nitrogen into organic compounds that function as components of cells and tissues. The two  
374 forms of nitrogen commonly used for assimilation are ammonia and nitrogen nitrate. Ammonia  
375 nitrogen is a suitable nitrogen source for assimilation because it is reduced more energetically than

377 nitrate. Ionized ammonia can be adsorbed from solution by cation exchange reactions with detritus,  
378 inorganic deposits, or soil. The adsorbed ammonia is loosely bound to the substrate and is easily  
379 released when the hydrochemical conditions change. At a given concentration of ammonia in the  
380 water column, a certain amount of ammonia is adsorbed and saturated at the available binding sites.  
381 When the concentration of ammonia in the water column decreases, some of the ammonia desorbs  
382 and rebalances with the new concentration. The higher the ammonia concentration in the water  
383 column, the more ammonia is adsorbed. When wetland substrates are exposed to oxygen, perhaps  
384 due to regular aeration, the adsorbed ammonium can be oxidized to nitrate. Ammonium ions ( $\text{NH}_4^+$ )  
385 are generally adsorbed on clay as exchangeable ions and are chemically adsorbed by humic  
386 substances or fixed to the clay lattice. It seems that these reactions can occur at the same time.

387 According to ammonium concentration analysis, it was found that the ammonium  
388 concentration was increasing from the upstream to downstream. In the upstream, the Candung with  
389 *Nelumbo nucifera* showed the best result with 99,11% removal of ammonium; meanwhile, the  
390 candung with *Nymphaea tetragona* had 33,23% removal, but after the candung with *Pistia stratiotes*  
391 had a negative result, which was higher than the influent. In the mid-stream, candung with *Nelumbo*  
392 *nucifera* and *Pistia stratiotes* has a similar result on ammonium removal, about 33%-36%. In the  
393 downstream, the ammonium concentration was found at 1,911 mg/L (*Nelumbo nucifera*), 1,169 mg/L  
394 (*Nymphaea tetragona*), 1,174 mg/L (*Pistia stratiotes*) with the range of ammonium removal 16%-17%.  
395 The candung with *Nelumbo nucifera* gave the best result in all three stream areas.

396 **Figure 6.** The nitrogen concentration in each effluent of Candung from upstream (1), mid-stream (2)  
397 and downstream (3)

### 398 **3.3 Community Responses on the Application of Candung to Maintain the Irrigation Water**

#### 399 **3.3.1 Respondent Demographic**

400 The results of the descriptive analysis of the demographics of the respondents aim to obtain  
401 an overview of the respondent's profile regarding age, education level, and land area. The results of  
402 the analysis obtained for the demographics of the respondents can be presented in Table 3 below.

**Table 3.** Respondent Demographics

Table 3 shows the demographics of respondents based on age, showing more respondents over 50 years with a distribution of 86.3%. Furthermore, it was followed by the respondents of 40-49 years (11.5%), 30-39 years (1.6%), and under 30 years (0.5%). Information from the distribution of respondents by age indicates that most of the members of Subak Lepud are old enough to work on the land they own.

In terms of respondent demographics based on education level (Table 3), Subak Lepud members dominantly have senior high school/equivalent education, namely 45.1%, followed by those with junior high school education (25.3%), elementary school (18.1%), and the least, bachelor's degree (11.5%). This information illustrates that the level of education of Subak Lepud members is still very low because the majority are below bachelor's degree, namely 96.6%. Based on this information, the members of Subak Lepud are still working on their agricultural land in the traditional way.

In terms of land ownership (Table 3), Subak Lepud members dominantly own more than 34 acres (36.3%) of land to cultivate. Next, followed by arable land ownership of 20 - 24 acres (17.6%), 30 - 34 acres (14.8%), 25 - 29 acres (14.3%), under 15 acres (10.4%), and the least, 15 - 19 acres (6.6%). Based on this information, it can be said that the land cultivated by Subak Lepud members is quite extensive. This descriptive analysis was carried out to find out the description of the respondents' responses regarding the statements in the research instrument, especially the variables studied. The analysis was conducted by calculating the average (mean) based on the percentage of respondents' responses to each indicator in the research variables, namely: knowledge (know), experience (exp), intention (intent), action (act), and potential (pot). The higher the average value obtained, the better the respondent's response to the indicator or variable.

**3.3.2 Community Knowledge**

The knowledge variable is defined as the understanding that Subak Lepud members have of the functions and benefits of Candung and water plants on agricultural land. In this study, the

431 variable knowledge is measured by five indicators, namely: (1) the function of improving water quality  
432 (know1); (2) the function of increasing land quality (know2); (3) the benefit of increasing biodiversity  
433 (know3); (4) the benefit of improving the quality of food products (know4); and (5) the benefit of  
434 reducing the use of pesticides (know5). The description of the knowledge variable of Subak Lepud  
435 members can be presented in Table 4 below.

436 **Table 4** Description of Respondents on Knowledge Variable (Know)

437 From the information in Table 4 above, it appears that the knowledge of Subak Lepud  
438 members regarding Candung and water plants on agricultural land was still relatively limited or  
439 lacking, considering the average perception obtained was 2.36. Other information that can be  
440 conveyed is that members of Subak Lepud understood the function of Candung and water plants to  
441 improve water quality because they had the highest average compared to other indicators (2.49).  
442 Meanwhile, the benefits of Candung and water plants for improving the quality of food products and  
443 reducing the use of pesticides were the lowest known to members of Subak Lepud, because they  
444 obtained the lowest average, which was equal to 2.30.

### 445 3.3.3 *Community Experience*

446 The experience variable is interpreted as the experience felt by Subak Lepud members in  
447 utilizing Candung and water plants on agricultural land. In this study, the experience variable (exp) is  
448 measured by four indicators, namely: (1) the use to reduce waste pollution (exp1); (2) the use as a  
449 medium for absorbing toxic in the field (exp2); (3) the use to maintain the balance of the land  
450 ecosystem (exp3); and (4) the use to produce healthy rice (exp4). The description of the experience  
451 variable (exp) of Subak Lepud members can be presented in Table 5 below.

452 **Table 5** Description of Respondents on Experience Variable (Exp)

453 Based on the explanation in Table 5 above, the experience of Subak Lepud members regarding  
454 the use of Candung and water plants on agricultural land was still relatively low, considering the  
455 average perception obtained was 2.92. In other words, Subak Lepud members did not take advantage

of the application of Candung and water plants on cultivated agricultural land. Other information that can be conveyed is the experience of using Candung and water plants to reduce waste pollution and toxic absorbing media on land tended to be practised by Subak Lepud members because they obtained an average that was equally greater than the other indicators (2.93).

### 3.3.4 Community Intention

The intention variable in this study is defined as the desire or interest of Subak Lepud members to cultivate Candung and water plants on agricultural land. In this study, the variable intention (intent) is measured by five indicators, namely: (1) interest in cultivation (intent1); (2) interest in preservation (intent2); (3) plan of use (intent3); (4) inviting other fellows (intent4); and (5) socialization of use (intent5). The description of the intention variable of Subak Lepud members can be presented in Table 6 below.

**Table 6** Description of Respondents on Intention Variable (Intent)

From Table 6 above, it appears that Subak Lepud members tended to be interested in using Candung and water plants on cultivated agricultural land with consideration of the average perception obtained at 3.17. Other information that can be conveyed is that the cultivation of Candung and water plants tended to be of interest to members of Subak Lepud because it obtained the highest average, namely, 3.19. Meanwhile, members of Subak Lepud were of very little interest in preserving and planning the use of Candung and water plants because they had the lowest average score, which was 3.15.

### 3.3.5 Community Action

The action variable (act) is interpreted as the reaction of Subak Lepud members to cultivate Candung and water plants on agricultural land. In this study, the action variable (act) was measured by five indicators, namely: (1) the construction of Candung and water plants at the inlet water (act1); (2) the construction of Candung and water plants together with all subak members (act2); (3) the selection of Candung and water plants that effectively absorb pollutants (act3); (4) the cultivation of

483 Candung and water plants with economic value (act4); and (5) the preservation of Candung and water  
484 plants for all subak members (act5).

485 The results of the description of the action variable (act) in Table 6 show that Subak Lepud  
486 members were quite enthusiastic about cultivating Candung and water plants on agricultural land,  
487 taking into account the average perception obtained by 3.15. Furthermore, it can be said that the  
488 construction of Candung and water plants at the inlet position is believed to be carried out by Subak  
489 Lepud members because it obtained the highest average compared to other indicators, namely, 3.19.  
490 Meanwhile, the response to the construction of Candung and water plants together with all subak  
491 members was the least, with an average of 3.13.

492 **Table 7** Description of Respondents on Action Variable (Act)

### 493 **3.3.6 Community Potential**

494 The potential variable (pot) is interpreted as the view of Subak Lepud members regarding  
495 the opportunities that can be generated from the cultivation of Candung and water plants on  
496 agricultural land. In this study, the potential variable (pot) is measured by five indicators, namely: (1)  
497 increasing the value of local wisdom of subak (pot1); (2) producing sustainable healthy food products  
498 (pot2); (3) creating educational tourist attractions (pot3); (4) adding economic value to all subak  
499 members (pot4); and (5) preserving biodiversity in the land (pot5).

500 The description of the potential variables (pots) of Subak Lepud members in Table 7 shows  
501 that Subak Lepud members quite believed the cultivation of Candung and water plants on agricultural  
502 land could provide promising opportunities in the future. This result is in accordance with the  
503 consideration of the average perception for the potential variable (pot) of 3.35. Furthermore, it can be  
504 said that the cultivation of Candung and water plants is believed to have the potential to increase the  
505 value of Subak's local wisdom because it obtained the highest average (3.43), followed by the  
506 potential to create educational tourist attractions (3.35), and produce sustainable healthy food  
507 products (3.35). The lowest response from Subak Lepud members was on the indicator of biodiversity  
508 preservation on land (3.32). The results of this analysis can provide clues that Subak Lepud members  
509 tended to believe that the results of the cultivation of Candung and water plants have the opportunity

511 to increase the value of local wisdom, create educational tourist attractions, and produce sustainable  
 512 healthy food products.

513 **Table 8** Description of Respondents on Potential Variable (Pot)

### 514 **3.3.7 Inferential Analysis**

515 The inferential analysis used in this research is path analysis. Path analysis is a development  
 516 of regression analysis that examines the causal relationships that occur in the variables studied, either  
 517 directly (direct effect) or indirectly (indirect effect). The use of the AMOS program in this study is to  
 518 help obtain a path diagram model simultaneously. Meanwhile, the use of regression analysis is to  
 519 obtain a path diagram model that needs to be done in stages.

520 Based on the results of data analysis using path analysis with the decomposition model, namely  
 521 the causal influence between variables, it can be identified the factors that can determine the potential  
 522 of cultivation of Candung and water plants in Subak Lepud. The variables studied include knowledge  
 523 (know) and experience (exp) as exogenous variables. Meanwhile, intention (intent) and action (act)  
 524 are identified as intervening (mediation) variables and potential (pot) variables as endogenous  
 525 variables in the path diagram model.

526 The path diagram model that is formed needs to be tested for model validation using the total  
 527 determination coefficient (Dillon et al., 1984) with the following formula:

$$528 \quad R^2_m = R^2_{pe1} \cdot R^2_{pe2} \cdot R^2_{pe3}$$

$$529 \quad R^2_m = 0.429 \times 0.494 \times 0.607 = 0.1286$$

$$530 \quad \text{Model Validation:} \quad 1 - R^2_m$$

$$531 \quad \text{Model Validation: } 0.9334 \text{ or } 93,34 \%$$

533 The results of the model validation mean that the diversity of the data can be explained by the  
534 path diagram model of 93.34%, while the remaining 6.66% is explained by other variables (which are  
535 not in the model) and errors. Thus, the results of the path analysis can be further explained by  
536 decomposing it into standardized regression coefficients. The decomposition of the results of the  
537 standardized path analysis (Table 8) shows that the five direct effect pathways have a significant  
538 effect (*p value* <0.05). In the indirect effect test using Sobel's test, three significant paths were  
539 obtained (*p value* <0.05).

540 In further explanation, it can be said that *knowledge* has a positive and significant effect on  
541 *intention* with a path coefficient (standardized) of 0.308. The results of this analysis indicate that the  
542 knowledge of the cultivation of Candung and water plants obtained will increase the interest of Subak  
543 Lepud members in using Candung and water plants on cultivated agricultural land. Likewise, the effect  
544 of *experience* on *intention* has a positive and significant influence with a path coefficient  
545 (standardized) of 0.393. This result means that the more experienced Subak Lepud members are in  
546 the cultivation of Candung and water plants, the more interest they have in using Candung and water  
547 plants on cultivated agricultural land.

548 **Table 9** Decomposition of Path Analysis Results (*Standardized*)

549 Description: S = Significant NS = Not Significant

550 Information from Table 9 above shows that *intention* has a positive and significant effect on  
551 *action* with a path coefficient (standardized) of 0.703. These results provide a direction to increase  
552 the interest of Subak Lepud members in cultivating Candung and water plants, which will escalate the  
553 application of Candung and water plants on their agricultural land. In other effects, *intention* has a  
554 positive and significant influence both directly and indirectly on *potential*, with a direct effect path  
555 coefficient (standardized) of 0.526 and an indirect effect path coefficient (standardized) of 0.221. The  
556 results of the analysis indicate that the increased interest of Subak Lepud members in cultivating  
557 Candung and water plants can provide a more promising potential for cultivated agricultural land if it  
558 is based on real and serious actions. Meanwhile, the *action* to cultivate Candung and water plants  
559 was found to have a positive and significant effect on *potential* with a path coefficient (standardized)



561 of 0.313. In order to clarify the results of the analysis obtained, a path diagram model can be presented  
562 in **Figure 7** below.

563 **Figure 7** Analysis Results Path Diagram Model (*Standardized*)

564 Based on the information in Table 8 and Figure 1 above, it can be found that *intention* derived  
565 from *experience* will have a greater impact on the *actions* that Subak Lepud members will take to  
566 cultivate Candung and water plants if sourced from *knowledge*. This finding certainly further confirms  
567 the *potential* obtained by Subak Lepud members from the results of cultivating Candung and water  
568 plants on cultivated agricultural land.

569 **4. CONCLUSIONS**

570 Candung is one of the local wisdom in Bali Island, acting as a constructed wetland that aims to  
571 maintain the irrigation water before entering the paddy fields. It is also a preservation of the paddy  
572 field ecosystem in order to prevent pollution and ensure the food material (rice) is safe. The effect of  
573 Candung in maintaining the water quality showed a good result in removing the water quality  
574 parameters, such as TSS, BOD, COD, and nutrients with certain water plants (*Nelumbo*  
575 *nucifera*, *Nymphaea tetragona*, *Pistia stratiotes*). The knowledge, behaviour, and action of the local  
576 Subak community were still limited, whereas they had positive perceptions and responses about  
577 Candung's potential as an agrotourism attraction in the village.

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**Table 1.** Recapitulation of Research Instrument Testing Results

No	Variable	Item	Validity Test (koef. r)	Reliability Test (koef. Cronbach Alpha)
1.	Knowledge	Know <sub>1</sub>	0.915	0.982
		Know <sub>2</sub>	0.963	
		Know <sub>3</sub>	0.970	
		Know <sub>4</sub>	0.931	
		Know <sub>5</sub>	0.970	
2.	Experience	Exp <sub>1</sub>	0.942	0.933
		Exp <sub>2</sub>	0.727	
		Exp <sub>3</sub>	0.947	
		Exp <sub>4</sub>	0.781	
3.	Intention	Intent <sub>1</sub>	0.934	0.964
		Intent <sub>2</sub>	0.858	
		Intent <sub>3</sub>	0.943	
		Intent <sub>4</sub>	0.819	
		Intent <sub>5</sub>	0.966	
4.	Action	Act <sub>1</sub>	0.742	0.945
		Act <sub>2</sub>	0.865	

No	Variable	Item	Validity Test (koef. r)	Reliability Test (koef. Cronbach Alpha)
		Act <sub>3</sub>	0.929	
		Act <sub>4</sub>	0.913	
		Act <sub>5</sub>	0.821	
5.	Potential	Pot <sub>1</sub>	0.743	0.943
		Pot <sub>2</sub>	0.881	
		Pot <sub>3</sub>	0.914	
		Pot <sub>4</sub>	0.802	
		Pot <sub>5</sub>	0.904	

**Table 2.** The BOD/COD ratio of each stream and candung

	<b>Raw water</b>	<b>Nelumbo nucifera</b>	<b>Nymphaea tetragona</b>	<b>Pistia stratiotes</b>
<b>Upstream</b>	0,40	0,03	0,11	0,05
<b>Mid-Stream</b>	0,04	0,11	0,35	0,05
<b>Downstream</b>	0,14	0,05	0,03	0,32

**Table 3.** Respondent Demographics

<b>Number</b>	<b>Description</b>	<b>Number of People</b>	<b>Percentage (%)</b>
<b>1</b>	<b>Age:</b>		
	• < 30 years	1 person	0.5
	• 30 - 39 years	3 people	1.6
	• 40 – 49 years	21 people	11.5
	• 50 – 59 years	88 people	48.4
	• > 59 years	69 people	37.9
<b>2</b>	<b>Education Level:</b>		
	• Elementary School	33 people	18.1
	• Junior High School	46 people	25.3
	• Senior High School/Equivalent	82 people	45.1
	• Bachelor's Degree	21 people	11.5
<b>3</b>	<b>Land Area:</b>		
	• < 15 acres	19 people	10.4
	• 15 - 19 acres	12 people	6.6

• 20 - 24 acres	32 people	17.6
• 25 - 29 acres	26 people	14.3
• 30 – 34 acres	27 people	14.8
• > 34 acres	66 people	36.3
<b>Total</b>	<b>182 people</b>	<b>100</b>



**Table 4** Description of Respondents on Knowledge Variable (Know)

	Description	Response (%)					Averaga (Mean)
		1	2	3	4	5	
1	The function of improving water quality (know1)	25.8	28.0	19.8	24.2	2.2	<b>2.49</b>
2	The function of increasing land quality (know2)	25.8	30.2	23.6	18.1	2.2	2.41
3	The benefit of increasing biodiversity (know3)	25.8	32.4	26.9	14.8	-	2.31
4	The benefit of improving the quality of food products (know4)	25.8	36.8	19.2	18.1	-	2.30
5	The benefit of reducing the use of pesticides (know5)	25.8	34.6	23.1	16.5	-	2.30
<b>Knowledge Variable (Know)</b>							<b>2.36</b>

**Table 5** Description of Respondents on Experience Variable (Exp)

	Description	Response (%)					Average (Mean)
		1	2	3	4	5	
1	The use to reduce waste pollution (exp1)	9.9	9.9	59.3	18.7	2.2	2.93
2	The use as a medium for absorbing toxic in the field (exp2)	9.9	9.9	57.1	23.1	-	<b>2.93</b>
3	The use to maintain the balance of the land ecosystem (exp3)	9.9	9.9	59.3	20.9	-	2.91
4	The use to produce healthy rice (exp4)	9.9	9.9	59.3	20.9	-	2.91
<b>Experience Variable (Exp)</b>							<b>2.92</b>

**Table 6** Description of Respondents on Intention Variable (Intent)

	Description	Response (%)					Average (Mean)
		1	2	3	4	5	
1	Interest in cultivation (intent1)	3.3	1.6	69.8	23.1	2.2	<b>3.19</b>
2	Interest in preservation (intent2)	3.3	1.6	72.0	23.1	-	3.15
3	Plan of use (intent3)	3.3	1.6	72.0	23.1	-	3.15
4	Inviting other fellows (intent4)	3.3	1.6	69.8	25.3	-	3.17
5	Socialization of use (intent5)	3.3	1.6	69.8	25.3	-	3.17
<b>Intention Variable (Intent)</b>							<b>3.17</b>

**Table 7** Description of Respondents on Action Variable (Act)

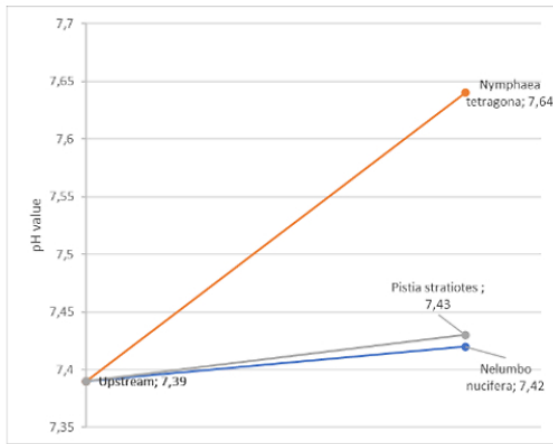
	Description	Response (%)					Average (Mean)
		1	2	3	4	5	
1	The construction of Candung and water plants at the inlet water (act1)	6.6	4.9	53.3	33.0	2.2	3.19
2	The construction of Candung and water plants together with all subak members (act2)	7.1	5.5	54.9	32.4	-	3.13
3	The selection of Candung and water plants that effectively absorb pollutants (act3)	6.6	4.4	57.7	31.3	-	3.14
4	The cultivation of Candung and water plants with economic value (act4)	6.6	4.2	57.9	31.3	-	3.14
5	The preservation of Candung and water plants for all subak members (act5)	6.6	4.4	57.6	31.4		3.14
<b>Action Variable (Act)</b>							<b>3.15</b>

**Table 8** Description of Respondents on Potential Variable (Pot)

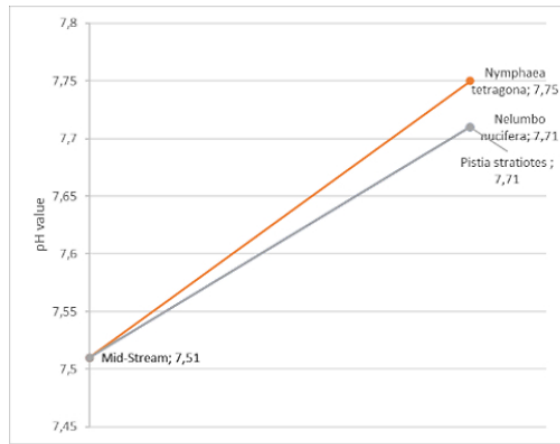
	Description	Response (%)					Average (Mean)
		1	2	3	4	5	
1	Increasing the value of local wisdom of subak (pot1)	3.3	-	49.5	45.1	2.2	<b>3.43</b>
2	Producing sustainable healthy food products (pot2)	3.3	2.2	51.1	43.4	-	3.35
3	Creating educational tourist attractions (pot3)	3.3	-	55.5	41.2	-	3.35
4	Adding economic value to all subak members (pot4)	3.3	-	57.7	39.0	-	3.32
5	Preserving biodiversity in the land (pot5)	3.3		57.8	38.9		3.32
<b>Educational Tourist Attraction Potential</b>							<b>3.35</b>

**Table 9** Decomposition of Path Analysis Results (*Standardized*)

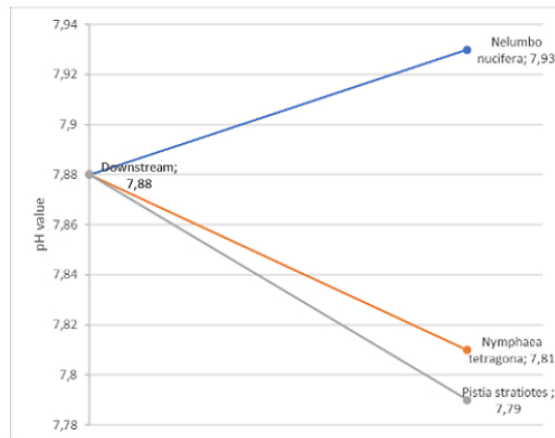
Effect	Causal Effect		
	Direct Effect	Indirect Effect	Total Effect
Intention ← Knowledge	0.308 <sup>s</sup>	-	0.308
Intention ← Experience	0.393 <sup>s</sup>	-	0.393
Action ← Knowledge	-	0.217 <sup>s</sup>	0.217
Action ← Experience	-	0.276 <sup>s</sup>	0.276
Action ← Intention	0.703 <sup>s</sup>	-	0.703
Potential ← Knowledge	-	0.230 <sup>s</sup>	0.230
Potential ← Experience	-	0.293 <sup>s</sup>	0.293
Potential ← Intention	0.526 <sup>s</sup>	0.221 <sup>s</sup>	0.747
Potential ← Action	0.313 <sup>s</sup>	-	0.313



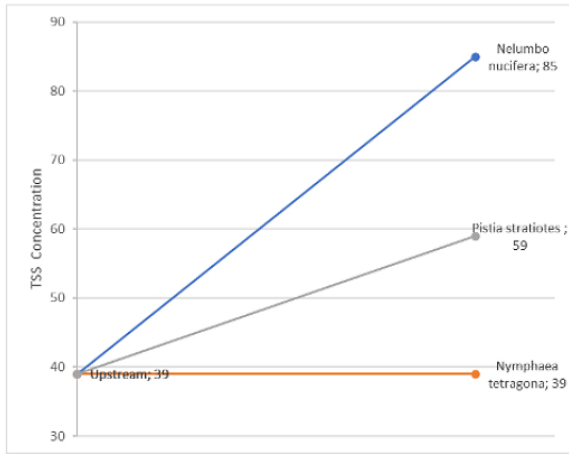
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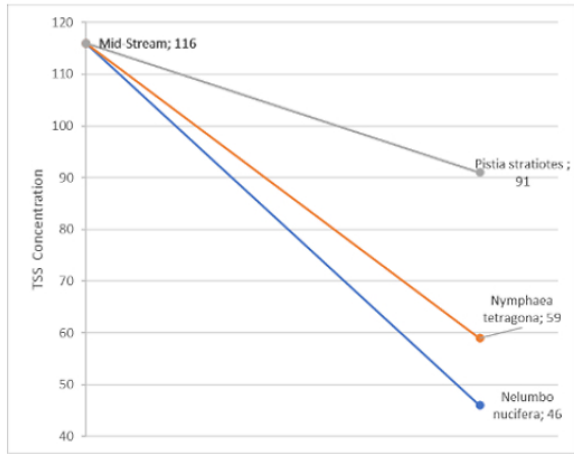
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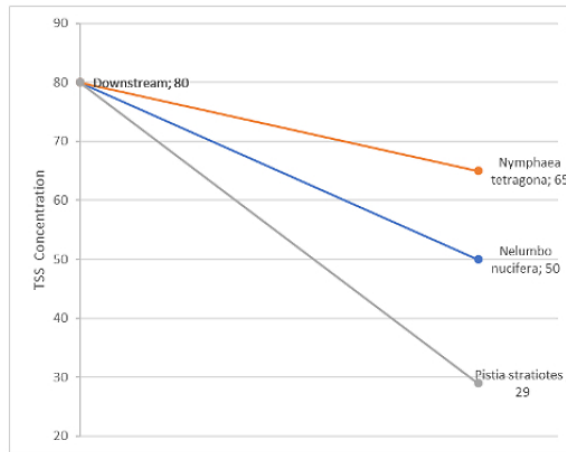
(3)



(1)

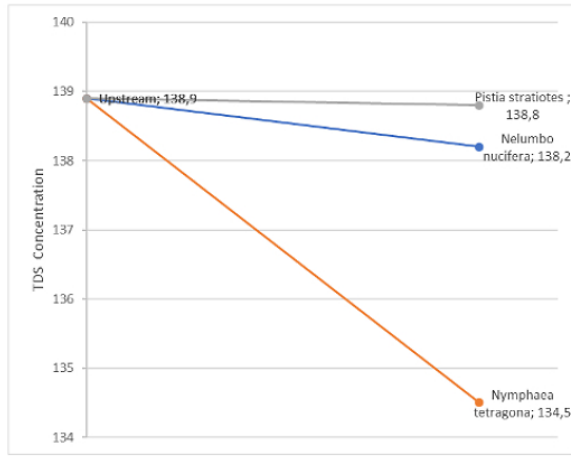


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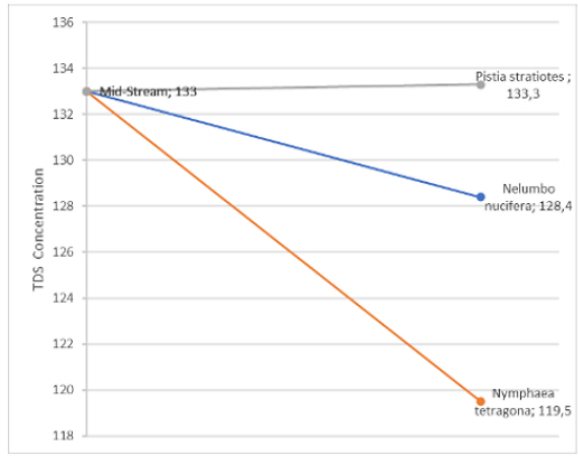


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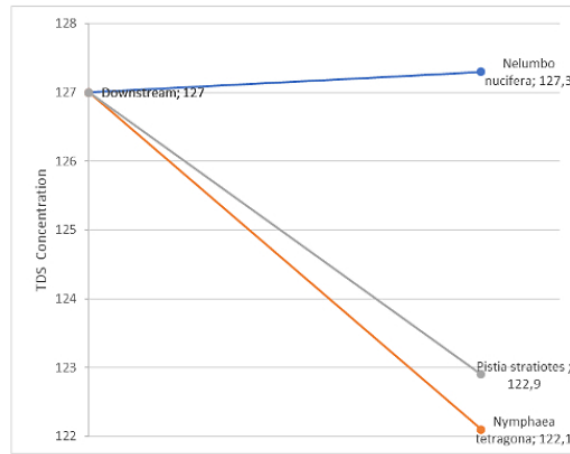




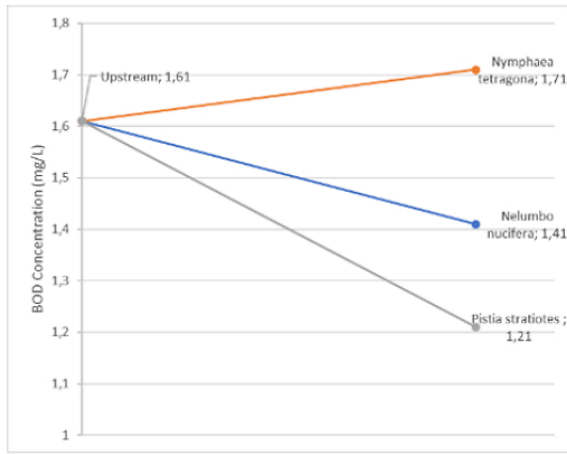
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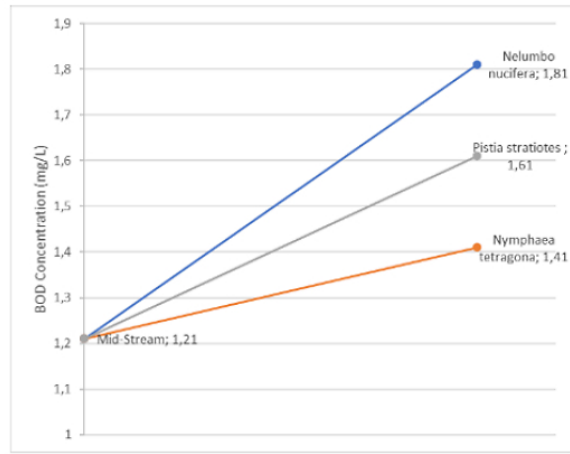
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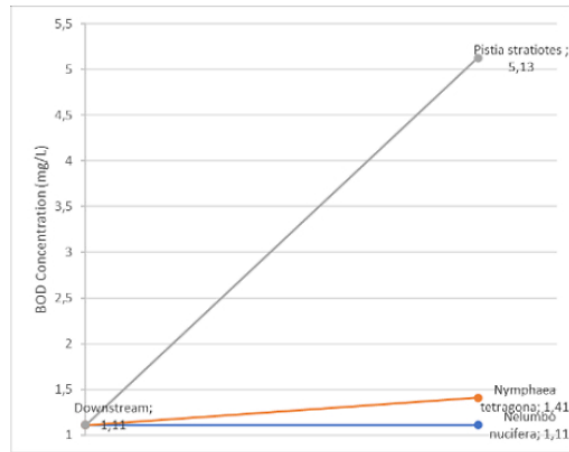
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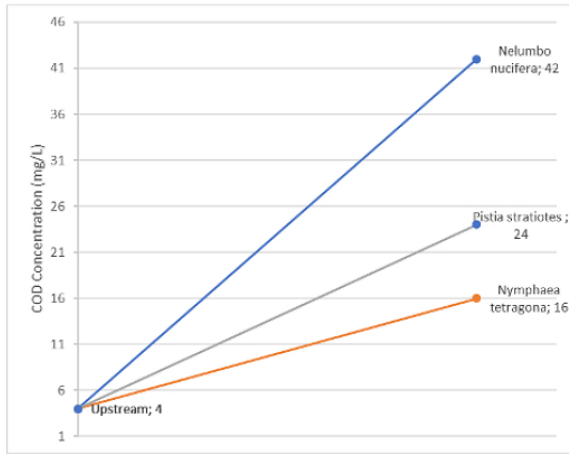
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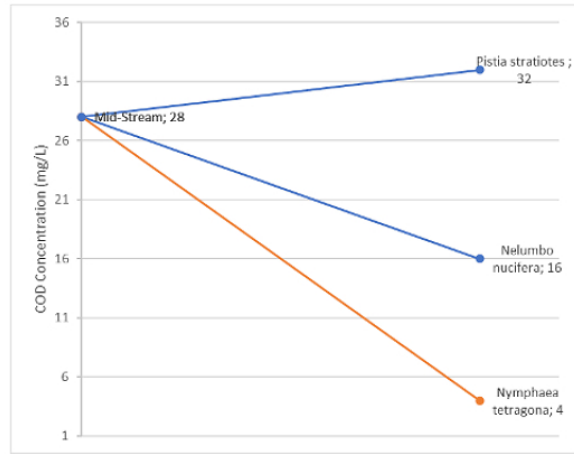
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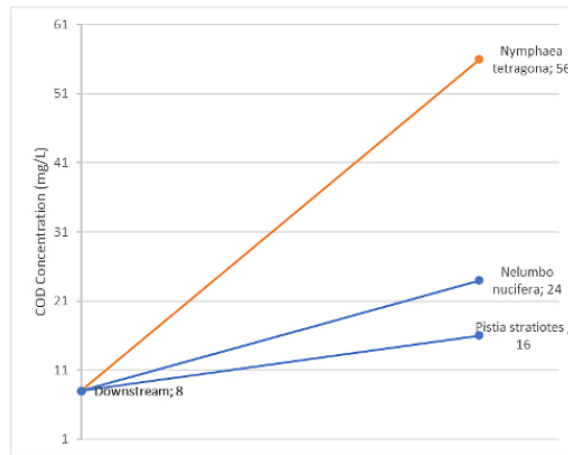
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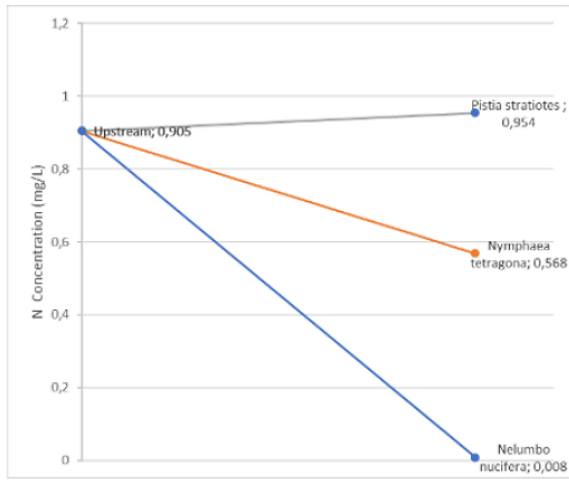
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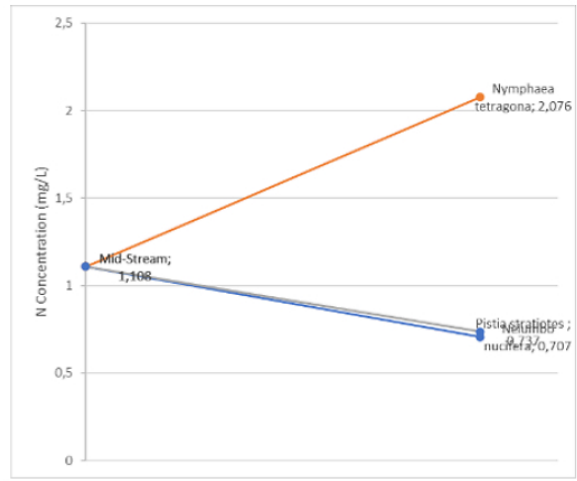
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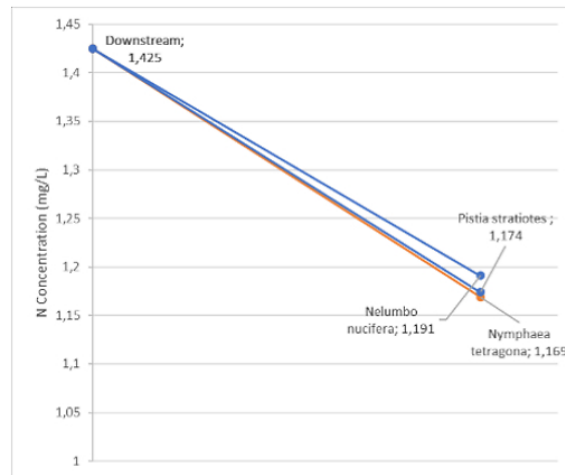
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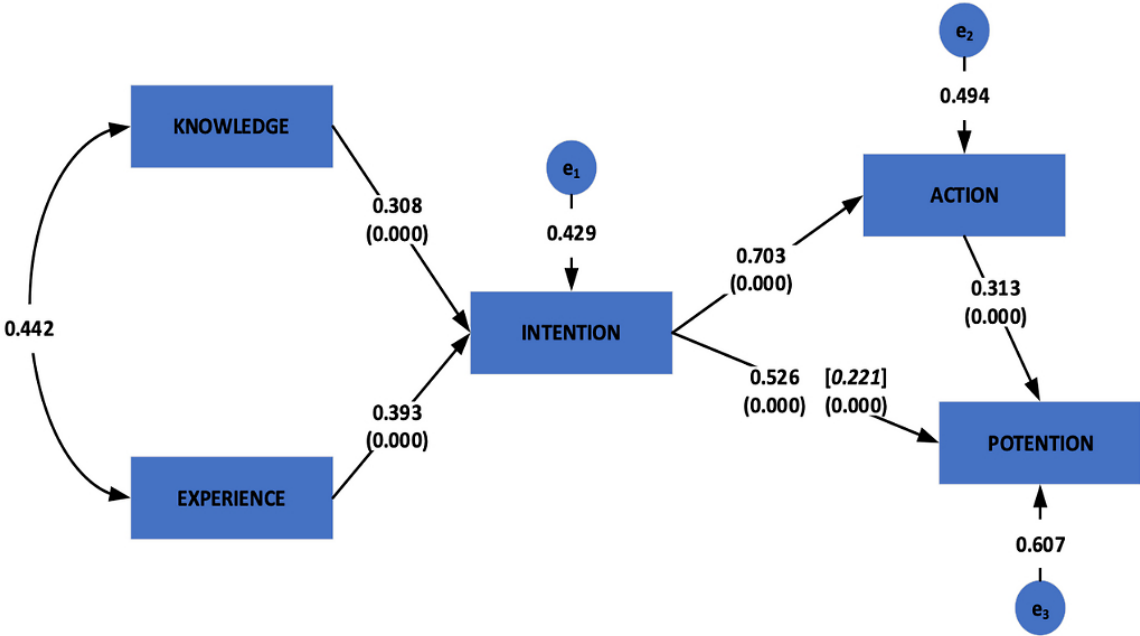
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(2)



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Figure 6 - [Download source file \(126.58 kB\)](#)

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Decision: **accept after changes suggested by reviewer**

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April 12, 2023

JEENG-04047-2023-01

Treatment Ability and Community Responses of Candung as an Appropriate Technology to Maintain Irrigation Water Quality

Dear Dr. I Ketut Sumantra,

I am pleased to inform you that your manuscript, entitled: Treatment Ability and Community Responses of Candung as an Appropriate Technology to Maintain Irrigation Water Quality, might be accepted for publication in our journal, pending some minor changes suggested by reviewers (see below).

Please revise your paper strictly according to the attached Reviewers comments. Your manuscript won't be taken into consideration without the revisions made according to the recommendations.

Authors of our journal are requested to prepare a revised version of their manuscript as soon as possible. This may ensure fast publication if an article is finally accepted.

Thank you for submitting your work to us.

Kindest regards,  
Prof. Gabriel Borowski  
Editor-in-Chief  
Journal of Ecological Engineering

**Files:**

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## Treatment Ability and Community Responses of Candung as an Appropriate Technology to Maintain Irrigation Water Quality

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### ABSTRACT

With the burgeoning population, the community activities ~~have expanded along the irrigation canal~~, such as laundering, washing, or even bathing, ~~have expanded along the irrigation canal~~. Consequently, some chemicals from those activities ~~is-are~~ released and pollute the water body. Besides, the discharge of wastewater into the irrigation system is also an issue of public health concern, because it creates an environment conducive to the reproduction of any pathogenic agent. Using Candung as constructed wetlands (CW)-like to treat the irrigation water in rice paddies would be an interesting tool for removing pollutants from the irrigation water. Candung, as a locally ~~used~~ CW in Bali Island, has been applied in the rice field long time ago. The present study ~~aims-aimed~~ to examine Candung as a local attached CW or treating irrigation water and ~~analyzing-analyse~~ the community awareness regarding the Candung application. The result showed a positive effect of Candung in maintaining the water quality parameters, such as TSS, BOD, COD, and nutrients with certain aquatic plants (*Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*). The knowledge, behaviour, and action of the local Subak community were still limited, whereas they had positive perceptions and responses about ~~Candung's-the~~ potential ~~of Candung~~ as an agrotourism attraction in the village as well.

**Keywords:** Candung, constructed wetland, irrigation water, *Nelumbo nucifera*, *Nymphaea tetragona*, *Pistia stratiotes*, agrotourism.

### INTRODUCTION

The irrigation water in villages in tropical countries is facing a reduction in water quality. It urgently needs to be concerned, so it can be effectively utilized as irrigation water for agriculture, aquaculture and potentially even household needs [1]. The rapid changes in land and water use due to dynamic farming intensity ~~is~~ constitute the main factor affecting water quality and quantity, ecology, and biodiversity globally [2]. The community activities have expanded along the irrigation canal, such as laundering, washing or even bathing. Solid waste is also dumped in the channel and causes floods during the rainy season because ~~of clogged~~ clogging with plastics. The type of pollutants within domestic wastewater can significantly vary based on location and pollutant type [3,4]. Consequently, some chemicals from those activities ~~is-are~~ released and pollute the water body. Besides, the discharge of wastewater into the irrigation system is also an issue of a public health concern as the dormant odour and suitable breeding of any pathogen [5,6].

The main source of agricultural irrigation water comes from surface water. Due to the spatial difference in water content in wetlands, streams and rivers, assessment is necessary to provide robust insights into the quality and quantity of water that enter the paddy fields [2,7]. Human activities around the paddy fields ~~are~~ influencing-influence the nutrient input in the irrigation system, which leads to water physicochemical conditions. The trophic state is defined by the factors that are related to nutrient contents, algae biomass and water transparency [8]. It causes water quality deterioration due to the discharge of untreated wastewater from the municipality [9,10].

Therefore, ~~a~~-pre-treatment is urgently needed before the irrigation water enters the paddy fields, using natural ~~depollution-treatment~~ process such as the constructed wetland. Agricultural practices have been developed using large amounts of chemical fertilizers and pesticides to sustain yields and productivity. This practice raised the level of nutrients reaching the aquifers, therefore contaminating the surface and groundwater [11]. Constructed wetland (CW) is ~~an~~ engineered systems that ~~simulates~~ processes from natural wetlands. With low external energy requirements, it improves water quality by means of a combination of physical, chemical, and biological processes [12]. The last few years showed that artificial or constructed wetlands were frequently used to treat wastewater due to their low-cost operation and maintenance, low energy consumption and ease of operation [13]. It consists of vegetation, substrates, microorganisms, and soil components to support the water treatment process [9,14]. Managing surface water pollution is critical for the economy, ecosystem, and human health concerns. CW can be installed in a pond that acts as a catchment area, flood controllers, and groundwater runoff. The CW has a role as trash trap and sedimentation storage so the water can be free of debris and sediment loads [15]. The present study ~~aims-aimed~~ to examine Candung as a local attached

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constructed wetland for treating irrigation water, with additional plants cultivation and ~~analyzing~~ analysing the community awareness regarding the Candung application.

## METHODOLOGY

### Study location

The research was conducted in a local irrigation water community named Subak Lepud. It is located in Baha Village, Badung Regency, Bali Island. It was supported by the Subak Lepud community and also farmers around the ~~subak~~ Subak area. Candungs were built in the corner of each paddy fields area and connected to the irrigation water system along the paddy fields area. It is a 1 x 1-meter area bordered by higher subsoil levels in order to maintain the water overflow. Within about 50 cm of depth, Candung could receive and hold about ~~0.5~~ 0.5 m<sup>3</sup> of water at a time. The solid content of irrigation water could be settled during the storage of Candung. There were three water plants used in Candung, such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*. Those plants are commonly used as decorative plants at home, in parks or gardens; meanwhile, in this research, they were used as emergent plants. The water will flow along the irrigation channel, enter Candung, which is installed in the entrance and flow to the paddy field.

### Water quality sampling

The irrigation water samples were collected from 15-20 cm below the surface in the month of September 2021. Those were taken in Candung box, which is placed right before the irrigation water enters the paddy fields. The water samples were taken at the upstream, midstream, and downstream points. Sample water was also taken from each Candung box right after those stream points. There are three Candung boxes at each point (upstream, midstream, downstream). Those Candungs represent the different water plants mentioned above. Accordingly, ~~there are~~ 12 water samples have been analysed in this study. The samples were preserved and analysed for physico-chemical characteristics. ~~The~~ Total dissolved solids (TDS) and total suspended solids (TSS) were measured by using filtration and gravimetric method. The accuracy of those methods is well ~~performed~~ documented in the scientific literature [16]. A 100 mL water sample was poured into weighed glass fibre filter of a specified pore size before starting the vacuum filtration. The filter was taken up after the completion of the filtration and placed in an aluminium dish in an oven at 100°C for 2-3 hours to completely vaporize the remaining water. Afterwards, the filter paper was weighed, and the gain in filter weight showed the TSS contents in mass per volume of the filtered sample (mg/L). The TDS were determined by the gravimetric method. After filtration for TSS analysis, the filtrate was placed in the oven at above 100°C until all the water was totally evaporated. The remaining mass of the residue represents the TDS in the water sample. The chemical compound such as dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), ammonium and phosphate were measured according to the standard method [17]. The samples were measured in the Laboratory of Health of Bali Province in triplicates ~~repeat~~.

### Community responses questionnaire

A community perspective has been analysed through a questionnaire with five variables, such as knowledge, behaviour, action, perception, tourism potential and health food material. The knowledge variable is interpreted as the understanding of the Subak Lepud members towards Candung and water plants on agricultural land. In this study, the knowledge variable was measured by six indicators, namely: (1) the benefits of Candung and water plants for environmental preservation; (2) the impact that occurs if Candung and water plants are not preserved; (3) the benefits of water plant species (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*) in aquatic ecosystems; (4) the impact of destroying and removing phytoremediation plant species from the environment; (5) the importance of conserving water plant species as phytoremediation/toxic absorbers; and (6) procedures for the preservation of Candung and water plants.

The attitude variable is interpreted as the reaction of Subak Lepud members from their understanding of Candung and water plants on agricultural land. In this study, the attitude variable was measured by five indicators, namely: (1) participating in conserving Candung and water plants to maintain the balance of the ecosystem; (2) participating in conserving Candung and water plants as an environmental conservation measure; (3) participating in conserving Candung and water plants for ~~subak~~ Subak irrigation which are polluted by waste; (4) taking part in maintaining the local wisdom of Candung and water plants because it can improve the ecological and economic welfare of the community; and (5) participating in conserving water plant species as phytoremediation/toxic absorbers. The action variable is defined as the actions committed by members of the Subak Lepud against Candung. In this study, the action variable was measured by five indicators, namely: (1) not creating Candung and planting water plants in Candung; (2) not making Candung and planting water plants so that the rice planting area is wider; (3) conserving Candung and water plant species because they have important ecological functions that are beneficial; (4) planting water plants in

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Candung (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*), because they have economic value; and (5) participating in the conservation of Candung and water plants that absorb poisons/contaminants. The perception variable is interpreted as the views of Subak Lepud members regarding the benefits of Candung on agricultural land. The perception variable is measured by five indicators, namely: (1) the sustainability of Candung and water plants can be beneficial for the balance of aquatic ecosystems; (2) the benefits of Candung and water plants in maintaining and improving water quality; (3) the benefits of Candung and water plant species for organisms that live in rice fields; (4) the benefits of preserving Candung and water plants to overcome water pollution that enters rice fields; and (5) the benefits of conserving Candung and water plants for the community.

The variable of the potential for educational tourist attractions is interpreted as the views of Subak Lepud members regarding the potential of Candung and water plants on agricultural land as educational tourist attractions and healthy food providers. In this study, the variable of the potential of educational tourist attractions was measured by five indicators, namely: (1) Candung and water plants (such as *Nelumbo nucifera*, *Nymphaea tetragona*) have ~~subak-Subak~~ local wisdom values; (2) Candung and water plants that absorb pollutants (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*) will be able to produce healthy food products; (3) Candung and pollutant-absorbing water plants (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*) can be used as educational tourist attractions; (4) support from subak members in the conservation of Candung and water plants (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*); and (5) a district/provincial government policy is needed for the conservation of Candung and water plants as educational tourist attractions.

Inferential analysis was carried out by using Path Analysis with the help of the Smart-PLS program. The analysis was first performed to evaluate the structural model by taking into account the  $Q^2$  predictive relevance model. The goal was to measure how well the observed values were generated by the model.  $Q^2$  is based on the coefficient of determination of all dependent variables. The value of  $Q^2$  has a range of  $0 < Q^2 < 1$ , the closer to 1, the better the model. In this structural model, there are two endogenous (dependent) variables, namely: Perception, Action and Potential, so three coefficients of determination ( $R^2$ ) can be determined, which are the basis for calculating the  $Q^2$  predictive relevance model.

To obtain data that has good calibration for each of the variables studied, the research instrument needs to be tested for its validity and reliability. ~~Based on this~~ Thus, it is important to carry out tests to ensure the level of validity and reliability of the research instrument is in accordance with the specified criteria. Testing the research instrument was carried out by means of a trial (pre-research) by distributing 35 questionnaires to Subak Lepud members. The validity test aims to measure whether the research instrument is valid or not. The research instrument is said to be valid if the instrument is able to accurately measure what is to be measured (Ghozali, 2009). Testing the validity of this instrument uses the validity of the criteria calculated through corrected item correlation analysis. Through this analysis, the research instrument is said to be valid if it has a correlation coefficient above 0.30. Meanwhile, the reliability test aims to measure the internal consistency of an indicator of a variable. High-reliability results provide confidence that all individual indicators are consistent with their measurements (Wijanto, 2008). This reliability test uses the one-shot method or is done only once, which is measured using Cronbach Alpha ( $\alpha$ ) analysis. A variable is said to be reliable if it has a Cronbach Alpha ( $\alpha$ ) value above 0.60 (Nunally, 1960 in Ghozali, 2009). The results of testing the research instrument from the questionnaire trial (n = 35 samples) that was carried out can be presented in Table 1 below

**Table 1.** Recapitulation of research instrument testing results

The information from Table 1 above shows that all statement items from five variables, namely knowledge, experience, intention, action and potential were valid (correlation coefficient was above 0.30) and showed a good level of reliability (Cronbach's Alpha correlation coefficient ( $\alpha$ ) was above 0.60). Thus, the research instrument (questionnaire) could be used and distributed to all predetermined target samples. The data collected was 182 units out of 200 units which were distributed to all members of Subak Lepud. The results of the further examination showed that the 182 data units had been filled in completely, so they were ready for further analysis.

## RESULTS AND DISCUSSION

### Candung as a locally appropriate technology

The silt that may be drifted along the irrigation system needs to be removed in a sedimentation chamber before entering the paddy fields. This Candung will help reduce the clogging irrigation system ~~and as well as~~ eliminate a large part of the particulate organic load and forms of nutrients entering ponds. The Candung pool

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If so, please separate it from Perception using 'as well as'

is shallow and sealed around to maintain the overflow. Soil is the main substrate of Candung ~~and covers with thickness~~ up to 50 cm ~~thick~~ and thus, ~~allowing it allows~~ the formation of wetland plants [9]. According to Kadlec [18], there are four main principles of constructed wetlands, including Candung. They are balancing the conversion rate of natural wetlands resulting from agriculture and urban development, improving the water quality after the treatment, flood control and supporting food production. Candung can be considered as part of the wastewater treatment system to provide physical and biological treatment. Vegetation, substrates, soils, microbes, and water are the essential components of the technique. To remove various contaminants, it employs complex processes involving physical, chemical, and biological mechanisms [9]. The wastewater treatment in Candung is commonly practiced through biological processes (like microbial activity and plant uptake) and physicochemical processes (like precipitation, adsorption, and sedimentation) [19]. As a system, Candung belongs to a free water surface constructed wetland (FWSF) which operates like a natural wetland. One of the important parts of Candung is the emergent plants which have several purposes and be mutual with the microorganism. The stems and submerged leaves ~~are supporting support~~ the growth of bacteria, and the leaves above the surface shade the water ~~and as well as~~ reduce the potential for rapid algae growth, ~~whereas;~~ ~~and~~ oxygen from the atmosphere is transported from the leaves down to the roots, which ~~supports~~ the plant growth.

Constructed wetlands (CWs) for wastewater treatment are a natural, simple, low construction and maintenance cost, and environmentally friendly method, representing alternative and promising solutions for environmental protection and preservation. CWs are most suitable for small areas and rural communities [20]. Water and nutrient recycling are emerging and part of water management. Proper wastewater treatment is an issue in sustainable development related to water demand and designed due to growing populations, whereas global climatic changes have increased water stress conditions, especially in limited water resource areas [21]. In constructed wetland systems, plants can play an important role in the removal of nutrients from wastewater compared to unplanted wetlands. Macrophytes can improve wastewater quality by helping to settle suspended solids, directly ~~uptake taking up~~ nutrients, and ~~provide providing~~ support for microbial flora [22].

Therefore, the seasonal selection of plants for constructed wetlands should be an important part of wastewater treatment management in a CW system. Most of the previous research on constructed wetlands covered one plant season, but the period of vegetative growth followed, culminating in death. After completion of a life cycle, plants leave, roots begin to die, and if plants remain in the CW, decay from the plant material will release nutrients back to the CW. Therefore, appropriate plants for the specific season will optimize the function of the constructed wetland.

#### Treatment ability of Candung

*The pH, total suspended solid (TSS), and total dissolved solid (TDS)*

The pH is one of the important water quality characteristics that represent the acidity or alkalinity of the water sample. A pH below 7.0 is considered acid, while ~~an alkaline is if~~ the pH is above 7.0 ~~is alkaline~~ (Sawyer et al., 2003). The hydrogen-ion concentration is very important to speed up the biochemical process, which is also depending on the current enzyme. The enzyme sometimes needs a certain pH value to ~~get achieve~~ the best reaction rather than a lower pH or higher pH. The pH affects the suitability of available water to support the living organism (Qasim, 1999; Tchobanoglous et al., 2002). Acidic water can affect the corrosion of metal; meanwhile, alkaline is presenting disinfection of the water. The normal drinking water pH range is around 6,5-8,5 (World Health Organisation (WHO), 2017). The pH in the 12 water samples showed a pH range between 7,0-8,0. The lowest pH was found at the upstream point with 7,39; meanwhile, the highest one was found at the downstream point after the Candung with *Nymphaea tetragona*. According to the pH analysis, the pH value from the upstream to the downstream increased from 7,39 to 7,88.

After passing through the Candung, there were some changes to the pH value. After the upstream, the pH value of the effluent of Candung with *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes* was 7,42; 7,64; 7,43, respectively. In the mid-stream, the pH was measured at 7,71; 7,75; 7,71, respectively, for three Candungs; meanwhile, the downstream were 7,93; 7,81; and 7,79. All the pH values of those effluents were covered by the national pH threshold of 6-9. According to Amic and Tadic (Amić & Tadić, 2018), the pH value of various stream water environments is in the range of 6,5 to 8,5, while pH below 4 (acid) and above 10 (base) creates a damaging living environment.

**Figure 1.** The pH value in each effluent of Candung from upstream (1), mid-stream (2) and downstream (3) The presence of various solid particles, whether suspended or dissolved, is characterized by the physical water quality (Soedjono et al., 2018; Wijaya & Soedjono, 2018). The solid shows the amount of particle or slurry left when the water is totally removed. The total solid is the content of solid in a sample after the sample has

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been dried at over 100°C for 24 hours and compared to the original mass of the sample. Total dissolved solids (TDS) is the sample that only can appear ~~in~~<sup>under</sup> dry conditions, while total suspended solids (TSS) still remain intact when ~~put~~<sup>placed</sup> into the water (Hamilton & Zhang, 2003; Ramesh & Jain, 2017). Total solid is represented by the sum of TDS and TSS. Water with a high dissolved solid concentration has an adverse impact on irrigation crops and plants; meanwhile, the highly suspended solid can cause a scum layer (floating solid) or build-up sediment (sink solid) (Ayoade et al., 2019; M. Faisal et al., 2015). The limits of TSS and TDS according to the national water quality standard for class II are 50 mg/L and 1000 mg/L, respectively. The TSS concentration increased from the upstream to the downstream due to the wastewater discharged along the stream.

The TSS measurement showed various changes in the TSS concentration in the effluents after passing through Candung. At the upstream point, the TSS of effluent increased after Candung with *Nelumbo nucifera* and *Pistia stratiotes* with 85 mg/L and 59 mg/L, respectively. There was no change of TSS after Candung with *Nymphaea tetragona* at 39 mg/L. TSS contributes to the sediment in the water body and potentially causes oxygen depletion. It is important to control the treatment process following the effluent regulation (Hudson, 2010; Wijaya et al., 2019). According to the national water quality standard classification (*Peraturan Pemerintah Republik Indonesia Nomor 82 Tahun 2001 Tentang Pengelolaan Kualitas Air Dan Pengendalian Pencemaran Air*, 2001), those concentrations were out of Class II water quality and belonged to Class III. The effluent TSS from Candung at the mid-stream and downstream has declined for all plants. The decreasing TSS indicates that the plants have promoted the solid to settle down as sediment. The highest removal of TSS was found in the mid-stream and downstream's Candung for *Nelumbo nucifera* (60,34%) and *Pistia stratiotes* (63,75%), respectively. [The](#) TSS concentration from the upstream, midstream, and downstream can be seen in Figure 2 below.

Total dissolved solids (TDS) indicate the dissolved salt in the water sample out of the suspended solid (SS). The TDS concentration is related to electrical conductivity or conductance. It shows the ability of water to transmit an electrical current that increases as the TDS concentration increases (Larrarte & Pons, 2011; Ramesh & Jain, 2017). TDS consists of various inorganic salts, such as sodium (Na<sup>+</sup>), calcium (Ca<sup>+</sup>), magnesium (Mg<sup>+</sup>), potassium (K<sup>+</sup>), chloride (Cl<sup>-</sup>), nitrates (NO<sup>3-</sup>), and bicarbonates (HCO<sup>3-</sup>). According to World Health Organization (WHO) standard for water quality, the permissible TDS for agriculture is in the range of 450-2000 mg/L (Jamei et al., 2020). In a stream and rivers, the conductivity capacity is altered by various factors, such as soil type, rock type, and the presence of dissolved solids (Vadde et al., 2018). TDS consists of ionic constituents that conduct electricity. TDS and bulk conductivities of sediment in the water body are generally higher at contaminated locations (Atekwana et al., 2004). Water with high TDS has been known to cause a detrimental effect on organism's health due to its adverse effect on feedstock (Sharma et al., 2017). A study from Devesa and Dietrich (Devesa & Dietrich, 2018) stated that the TDS also could represent the mineral content in the water body and affect the taste of the water. It can be considered with a concentration of TDS > 150 mg/L. The TDS analysis in this study showed that the TDS concentration was very low under the national water quality standard classification (*Peraturan Pemerintah Republik Indonesia Nomor 82 Tahun 2001 Tentang Pengelolaan Kualitas Air Dan Pengendalian Pencemaran Air*, 2001), which is 1000 mg/L.

**Figure 2.** The TSS concentration in each effluent of Candung from upstream (1), mid-stream (2) and downstream (3)

TDS in the upstream point was measured at 138,9 mg/L, while in the mid-stream and downstream was 133 mg/L and 127 mg/L, respectively. Candung has no significant effect on the TDS concentration after the water passes it through. The lowest TDS concentration from the Candung was found at the mid-stream point after Candung with *Nymphaea tetragona*, which was 119,5 mg/L. A low TDS is also found in the study by [Masood Mazood](#) et al. (Mazood et al., 2023), which is in a range of 99,6-101,2 mg/L with a standard value in the range of 400-500 mg/L. The decline of TDS concentration after all Candungs is presented below in Figure 3.

**Figure 3.** The TDS concentration in each effluent of Candung from upstream (1), mid-stream (2) and downstream (3)

#### *Biological oxygen demand (BOD)*

An enormous BOD concentration in the water body damages the water quality. It causes a low dissolved oxygen (DO) condition and an unfavourable life environment for the aquatic organism. BOD and DO have an exchange relationship with the riverbed, nitrification and denitrification (Koklu, 2009). BOD represents the total oxygen consumption to break down the organic material, which is performed by aerobic biological microorganisms (G. H. Faisal et al., 2020; Gu et al., 2013). It provides [the](#) information about available

biodegradable fraction which is loaded in the water (Jouanneau et al., 2013). The decrease in BOD is possibly caused by the oxidation of organic matter, which provides the energy resource for the microorganism metabolic process and is synthesized into cell mass (Marcato et al., n.d.). BOD is a commonly used parameter for assessing the biodegradability of dissolved organic matter in the water bodies (Simon et al., 2011).

**Figure 4.** The BOD concentration in each effluent of Candung from upstream (1), mid-stream (2) and downstream (3)

The aerobic microbiological degradation and sedimentation/filtration processes are the primary causes of BOD decrease. In subsurface flow wetlands, organic molecules can be destroyed both aerobically and anaerobically. Atmospheric oxygen diffusion, convection (wind effect), and/or macrophyte root transfer into the plant rhizosphere can provide oxygen for aerobic breakdown. Without oxygen, anaerobic organic elimination might take place inside the media pores. Anaerobic degradation is a two-step process undertaken by anaerobic heterotrophic bacteria in wetlands. Acid-forming bacteria synthesize organic materials into new cells, organic acids, and alcohols in the first phase (fermentation). Methane-forming bacteria, in the second stage, continue the oxidation (methanogenesis) by turning organic molecules into new bacterial cells, methane, and carbon dioxide. In the anaerobic zones of wetlands, fermentation and methanogenesis occur (Abedi & Mojiri, 2019; Kadlec & Wallace, 2008). The BOD concentration ~~since from~~ the upstream is in the range of 1-5 mg/L (Figure 4), which belongs to the water class I-III according to the national water quality standard (PP No.8/2001). ~~The~~ BOD was classified as low BOD concentration in all streams. In the upstream, the BOD was measured at 1,61 mg/L; in the midstream was 1,21 mg/L and in the downstream was 1,11 mg/L. The BOD decreased from the upstream to the downstream, which indicates the removal along the stream. The role of water plants has shown the changes of BOD in the stream water. The lowest BOD concentration was found in Candung upstream area with *Pistia stratiotes* with 1,21 mg/L. In the midstream, the BOD was found to increase to 1,81mg/L in Candung with *Nelumbo nucifera*, and in the downstream, there were significant changes of the BOD in Candung with *Pistia stratiotes* with 5,13 mg/L. The increase in BOD indicates that more dissolved oxygen in the stream is depleted. It could be caused by the settlement of debris, leaves, woods, dead plants and animal that becomes biomass and carbon sources.

#### Chemical oxygen demand (COD)

COD is described as the number of oxygen equivalents used in oxidizing the organic matter of samples by strong oxidizing agents such as dichromate or permanganate. The higher the chemical oxygen demand, the ~~higher greater~~ the concentration of pollution in the water sample (G. H. Faisal et al., 2020). COD is considered one of the most important water quality parameters of wastewater. The typical BOD/COD ratio for untreated household wastewater is 0.3–0.8; a BOD/COD ratio of 0.5 or above indicates that the available organics are easily degradable by microbes, whilst a ratio below 0.3 indicates that the available organics are harder to ~~breakdown-break down~~ by microorganisms (Kadlec & Wallace, 2008). According to the results of COD concentration after passing through each Candung, the effluent of Candung at the upstream and downstream gave negative results or significantly increased the COD. The BOD/COD ratio was found very low in all water sources (upstream, middle stream and downstream), below the threshold value to provide a proper environment for the microorganism, which is at least 0,5 or above. It results in low organic removal percentages because of the decrease in microbial activities to degrade the organic matter. A low BOD/COD ratio gives more insight into the COD concentration, whereas the organic matter that has to be degraded with chemical oxidants, such as potassium dichromate, is higher than the biodegradable (BOD). Besides, the presence of humic material in *Candung* also contributes to the higher COD concentration. Humic substances contain carbon, hydrogen, oxygen, nitrogen and small amounts of sulphur and phosphorus. ~~The H~~humic substances contained in products are commonly used in agriculture as part of the fertilizer, but on the other side, their rise is also a sign of organic pollutant levels, colour intensity, and chemical activities in the water (Rupiasih, 2016).

**Figure 5.** The COD concentration in each effluent of Candung from upstream (1), mid-stream (2) and downstream (3)

**Table 2.** The BOD/COD ratio of each stream and candung

#### Nutrient content

The most important organic forms of nitrogen in constructed wetlands are ammonium ( $\text{NH}_4^+$ ), nitrite ( $\text{NO}_2^-$ ), and nitrate ( $\text{NO}_3^-$ ). Gaseous nitrogen can be present as dinitrogen ( $\text{N}_2$ ), nitrous oxide ( $\text{N}_2\text{O}$ ), nitrous oxide ( $\text{NO}_2$  and  $\text{N}_2\text{O}_4$ ), and ammonia ( $\text{NH}_3$ ). Various forms of nitrogen are always involved in the chemical conversion of inorganic compounds to organic compounds and from organic compounds to inorganic compounds (Abba et al., 2021). Some of these processes require energy (usually from an organic carbon

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**Commented [A6]:** Please, cite Table 2 in the text.

source) to continue, while others release the energy that the organism uses for growth and survival. All of these transformations are necessary for the normal functioning of wetland ecosystems, and most chemical changes are facilitated by the production of enzymes and catalysts by organisms that benefit them (Vymazal, 2007). Ammonia is converted from its organic form through a complex, energy-releasing, multi-step biochemical process. In some cases, this energy is used by the microorganisms for growth and ammonia is incorporated directly into the microbial biomass. Nitrogen assimilation refers to various biological processes that convert inorganic forms of nitrogen into organic compounds that function as components of cells and tissues. The two forms of nitrogen commonly used for assimilation are ammonia and nitrogen nitrate. Ammonia nitrogen is a suitable nitrogen source for assimilation because it is reduced more energetically than nitrate. Ionized ammonia can be adsorbed from solution by cation exchange reactions with detritus, inorganic deposits, or soil. The adsorbed ammonia is loosely bound to the substrate and is easily released when the hydrochemical conditions change. At a given concentration of ammonia in the water column, a certain amount of ammonia is adsorbed and saturated at the available binding sites. When the concentration of ammonia in the water column decreases, some of the ammonia desorbs and rebalances with the new concentration. The higher the ammonia concentration in the water column, the more ammonia is adsorbed. When wetland substrates are exposed to oxygen, perhaps due to regular aeration, the adsorbed ammonium can be oxidized to nitrate. Ammonium ions ( $\text{NH}_4^+$ ) are generally adsorbed on clay as exchangeable ions and are chemically adsorbed by humic substances or fixed to the clay lattice. It seems that these reactions can occur at the same time.

According to ammonium concentration analysis, it was found that the ammonium concentration was increasing from the upstream to downstream. In the upstream, the Candung with *Nelumbo nucifera* showed the best result with 99,11% removal of ammonium; meanwhile, the candung with *Nymphaea tetragona* had 33,23% removal, but after the candung with *Pistia stratiotes* had a negative result, which was higher than the influent. In the mid-stream, candung with *Nelumbo nucifera* and *Pistia stratiotes* has a similar result on ammonium removal, about 33%-36%. In the downstream, the ammonium concentration was found at 1,911 mg/L (*Nelumbo nucifera*), 1,169 mg/L (*Nymphaea tetragona*), 1,174 mg/L (*Pistia stratiotes*) with the range of ammonium removal 16%-17%. The candung with *Nelumbo nucifera* gave the best result in all three stream areas.

**Figure 6.** The nitrogen concentration in each effluent of Candung from upstream (1), mid-stream (2) and downstream (3)

### Community responses on the application of Candung to maintain the irrigation water

#### Respondent demographic

The results of the descriptive analysis of the demographics of the respondents aim to obtain an overview of the respondent's profile regarding age, education level, and land area. The results of the analysis obtained for the demographics of the respondents can be presented in Table 3 below.

#### Table 3. Respondent demographics

Table 3 shows the demographics of respondents based on age, showing more respondents over 50 years with a distribution of 86.3%. Furthermore, it was followed by the respondents of 40-49 years (11.5%), 30-39 years (1.6%), and under 30 years (0.5%). The information from the distribution of respondents by age indicates that most of the members of Subak Lepud are old enough to work on the land they own.

In terms of respondent demographics based on education level (Table 3), Subak Lepud members dominantly have senior high school/equivalent education, namely 45.1%, followed by those with junior high school education (25.3%), elementary school (18.1%), and the least, bachelor's degree (11.5%). This information illustrates that the level of education of Subak Lepud members is still very low because the majority are below bachelor's degree, namely 96.6%. Based on this information, the members of Subak Lepud are still working on their agricultural land in the traditional way.

In terms of land ownership (Table 3), Subak Lepud members dominantly own more than 34 acres (36.3%) of land to cultivate. Next, followed by arable land ownership of 20 - 24 acres (17.6%), 30 - 34 acres (14.8%), 25 - 29 acres (14.3%), under 15 acres (10.4%), and the least, 15 - 19 acres (6.6%). Based on this information, it can be said that the land cultivated by Subak Lepud members is quite extensive. This descriptive analysis was carried out to find out the description of the respondents' responses regarding the statements in the research instrument, especially the variables studied. The analysis was conducted by calculating the average (mean) based on the percentage of respondents' responses to each indicator in the research variables, namely: knowledge (know), experience (exp), intention (intent), action (act), and potential (pot). The higher the average value obtained, the better the respondent's response to the indicator or variable.

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**Commented [A9]:** Please, cite Figure 6 in the text.

#### *Community knowledge*

The knowledge variable is defined as the understanding that Subak Lepud members have of the functions and benefits of Candung and water plants on agricultural land. In this study, the variable knowledge is measured by five indicators, namely: (1) the function of improving water quality (know1); (2) the function of increasing land quality (know2); (3) the benefit of increasing biodiversity (know3); (4) the benefit of improving the quality of food products (know4); and (5) the benefit of reducing the use of pesticides (know5). The description of the knowledge variable of Subak Lepud members can be presented in Table 4 below.

**Table 4.** Description of respondents on knowledge variable (know)

From the information in Table 4 above, it appears that the knowledge of Subak Lepud members regarding Candung and water plants on agricultural land was still relatively limited or lacking, considering the average perception obtained was 2.36. Other information that can be conveyed is that members of Subak Lepud understood the function of Candung and water plants to improve water quality because they had the highest average compared to other indicators (2.49). Meanwhile, the benefits of Candung and water plants for improving the quality of food products and reducing the use of pesticides were the lowest known to members of Subak Lepud, because they obtained the lowest average, which was equal to 2.30.

#### *Community experience*

The experience variable is interpreted as the experience felt by Subak Lepud members in utilizing Candung and water plants on agricultural land. In this study, the experience variable (exp) is measured by four indicators, namely: (1) the use to reduce waste pollution (exp1); (2) the use as a medium for absorbing toxic in the field (exp2); (3) the use to maintain the balance of the land ecosystem (exp3); and (4) the use to produce healthy rice (exp4). The description of the experience variable (exp) of Subak Lepud members can be presented in Table 5 below.

**Table 5.** Description of respondents on experience variable (Exp)

Based on the basis of on the explanation in Table 5 above, the experience of Subak Lepud members regarding the use of Candung and water plants on agricultural land was still relatively low, considering the average perception obtained was 2.92. In other words, Subak Lepud members did not take advantage of the application of Candung and water plants on cultivated agricultural land. Other information that can be conveyed is the experience of using Candung and water plants to reduce waste pollution and toxic absorbing media on land tended to be practised by Subak Lepud members, because they obtained an average that was equally greater than the other indicators (2.93).

#### *Community intention*

The intention variable in this study is defined as the desire or interest of Subak Lepud members to cultivate Candung and water plants on agricultural land. In this study, the variable intention (intent) is measured by five indicators, namely: (1) interest in cultivation (intent1); (2) interest in preservation (intent2); (3) plan of use (intent3); (4) inviting other fellows (intent4); and (5) socialization of use (intent5). The description of the intention variable of Subak Lepud members can be presented in Table 6 below.

**Table 6.** Description of respondents on intention variable (Intent)

From Table 6 above, it appears that Subak Lepud members tended to be interested in using Candung and water plants on cultivated agricultural land with consideration of the average perception obtained at 3.17. Other information that can be conveyed is that the cultivation of Candung and water plants tended to be of interest to members of Subak Lepud because it obtained the highest average, namely, 3.19. Meanwhile, members of Subak Lepud were of very little interest in preserving and planning the use of Candung and water plants because they had the lowest average score, which was 3.15.

#### *Community action*

The action variable (act) is interpreted as the reaction of Subak Lepud members to cultivate Candung and water plants on agricultural land. In this study, the action variable (act) was measured by five indicators, namely: (1) the construction of Candung and water plants at the inlet water (act1); (2) the construction of Candung and water plants together with all subak-Subak members (act2); (3) the selection of Candung and water plants that effectively absorb pollutants (act3); (4) the cultivation of Candung and water plants with economic value (act4); and (5) the preservation of Candung and water plants for all subak members (act5).

The results of the description of the action variable (act) in Table 6 show that Subak Lepud members were quite enthusiastic about cultivating Candung and water plants on agricultural land, taking into account the average perception obtained by 3.15. Furthermore, it can be said that the construction of Candung and water plants at the inlet position is believed to be carried out by Subak Lepud members because it obtained the

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highest average compared to other indicators, namely, 3.19. Meanwhile, the response to the construction of Candung and water plants together with all subak members was the least, with an average of 3.13.

**Table 7.** Description of respondents on action variable (Act)

#### *Community potential*

The potential variable (pot) is interpreted as the view of Subak Lepud members regarding the opportunities that can be generated from the cultivation of Candung and water plants on agricultural land. In this study, the potential variable (pot) is measured by five indicators, namely: (1) increasing the value of local wisdom of subak (pot1); (2) producing sustainable healthy food products (pot2); (3) creating educational tourist attractions (pot3); (4) adding economic value to all subak members (pot4); and (5) preserving biodiversity in the land (pot5).

The description of the potential variables (pots) of Subak Lepud members in Table 7 shows that Subak Lepud members quite believed the cultivation of Candung and water plants on agricultural land could provide promising opportunities in the future. This result is in accordance with the consideration of the average perception for the potential variable (pot) of 3.35. Furthermore, it can be said that the cultivation of Candung and water plants is believed to have the potential to increase the value of Subak's local wisdom, because it obtained the highest average (3.43), followed by the potential to create educational tourist attractions (3.35), and produce sustainable healthy food products (3.35). The lowest response from Subak Lepud members was on the indicator of biodiversity preservation on land (3.32). The results of this analysis can provide clues that Subak Lepud members tended to believe that the results of the cultivation of Candung and water plants have the opportunity to increase the value of local wisdom, create educational tourist attractions, and produce sustainable healthy food products.

**Table 8.** Description of respondents on potential variable (pot)

#### *Inferential analysis*

The inferential analysis used in this research is path analysis. Path analysis is a development of regression analysis that examines the causal relationships that occur in the variables studied, either directly (direct effect) or indirectly (indirect effect). The use of the AMOS program in this study is to help obtain a path diagram model simultaneously. Meanwhile, the use of regression analysis is to obtain a path diagram model that needs to be done in stages.

Based on the basis of the results of data analysis using path analysis with the decomposition model, namely the causal influence between variables, it can be identified the factors that can determine the potential of cultivation of Candung and water plants in Subak Lepud can be identified. The variables studied include knowledge (know) and experience (exp) as exogenous variables. Meanwhile, intention (intent) and action (act) are identified as intervening (mediation) variables and potential (pot) variables as endogenous variables in the path diagram model.

The path diagram model that is formed needs to be tested for model validation using the total determination coefficient (Dillon et al., 1984) with the following formula:

$$R^2_m = R^2_{pe1} \cdot R^2_{pe2} \cdot R^2_{pe3}$$

$$R^2_m = 0.429 \times 0.494 \times 0.607 = 0.1286$$

$$\text{Model Validation: } 1 - R^2_m$$

$$\text{Model Validation: } 0.9334 \text{ or } 93.34\%$$

The results of the model validation mean that the diversity of the data can be explained by the path diagram model of 93.34%, while the remaining 6.66% is explained by other variables (which are not in the model) and errors. Thus, the results of the path analysis can be further explained by decomposing it into standardized regression coefficients. The decomposition of the results of the standardized path analysis (Table 8) shows that the five direct effect pathways have a significant effect (p value <0.05). In the indirect effect test using Sobel's test, three significant paths were obtained (p value <0.05).

In further explanation, it can be said that *knowledge* has a positive and significant effect on *intention* with a path coefficient (standardized) of 0.308. The results of this analysis indicate that the knowledge of the cultivation of Candung and water plants obtained will increase the interest of Subak Lepud members in using Candung and water plants on cultivated agricultural land. Likewise, the effect of *experience* on *intention* has a positive and significant influence with a path coefficient (standardized) of 0.393. This result means that the more experienced Subak Lepud members are in the cultivation of Candung and water plants, the more interest they have in using Candung and water plants on cultivated agricultural land.

**Table 9.** Decomposition of path analysis results (standardized)

Description: S = Significant NS = Not Significant



The information from Table 9 above shows that *intention* has a positive and significant effect on *action* with a path coefficient (standardized) of 0.703. These results provide a direction to increase the interest of Subak Lepud members in cultivating Candung and water plants, which will escalate the application of Candung and water plants on their agricultural land. In other effects, *intention* has a positive and significant influence both directly and indirectly on *potential*, with a direct effect path coefficient (standardized) of 0.526 and an indirect effect path coefficient (standardized) of 0.221. The results of the analysis indicate that the increased interest of Subak Lepud members in cultivating Candung and water plants can provide a more promising potential for cultivated agricultural land if it is based on real and serious actions. Meanwhile, the *action* to cultivate Candung and water plants was found to have a positive and significant effect on *potential* with a path coefficient (standardized) of 0.313. In order to clarify the results of the analysis obtained, a path diagram model can be presented in **Figure 7** below.

**Figure 7.** Analysis results path diagram model (Standardized)

Based on the basis of the information in Table 8 and Figure 1 above, it can be found that *intention* derived from *experience* will have a greater impact on the *actions* that Subak Lepud members will take to cultivate Candung and water plants if sourced from *knowledge*. This finding certainly further confirms the *potential* obtained by Subak Lepud members from the results of cultivating Candung and water plants on cultivated agricultural land.

## CONCLUSIONS

Candung is one of the local wisdom in Bali Island, acting as a constructed wetland that aims to maintain the irrigation water before entering the paddy fields. It is also a preservation of the paddy field ecosystem in order to prevent pollution and ensure the food material (rice) is safe. The effect of Candung in maintaining the water quality showed a good result in removing the water quality parameters, such as TSS, BOD, COD, and nutrients with certain water plants (*Nelumbo nucifera*, *Nymphaea tetragona*, *Pistia stratiotes*). The knowledge, behaviour, and action of the local Subak community were still limited, whereas they had positive perceptions and responses about Candung's potential as an agrotourism attraction in the village.

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Kepada: Journal of Ecological Engineering &lt;office@jeeng.net&gt;

Dear Editor

Herewith, I am sending the final version of our work with small corrections on the affiliation details. Kindly, we request to complete the name of 1st affiliation into: **Rural and Regional Planning Study Program, Universitas Mahasaraswati Denpasar, Jalan Kamboja No. 11A, Dangin Puri, Kec. Denpasar Utara, Kota Denpasar, Bali 80233, Indonesia** and also a correction for the postal code on the 2nd affiliation change from **80236** to **80233**. Please find below the attached PDF with the correction signs. Thank you for your kind attention.

Best regards

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## Treatment Ability and Community Responses of Candung as an Appropriate Technology to Maintain Irrigation Water Quality

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### ABSTRACT

With the burgeoning population, the community activities, such as laundering, washing, or even bathing, have expanded along the irrigation canal. Consequently, some chemicals from those activities are released and pollute the water body. Besides, the discharge of wastewater into the irrigation system is also an issue of public health concern, because it creates an environment conducive to the reproduction of any pathogenic agent. Using candung as constructed wetlands (CW)-like to treat the irrigation water in rice paddies would be an interesting tool for removing pollutants from the irrigation water. Candung, as a locally used CW in Bali Island, has been applied in the rice field long time ago. The present study aimed to examine candung as a local attached CW or treating irrigation water and analyse the community awareness regarding the candung application. The result showed a positive effect of candung in maintaining the water quality parameters, such as TSS, BOD, COD, and nutrients with certain aquatic plants (*Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*). The knowledge, behaviour, and action of the local subak community were still limited, whereas they had positive perceptions and responses about candung the potential of candung as an agrotourism attraction in the village as well.

**Keywords:** candung, constructed wetland, irrigation water, *Nelumbo nucifera*, *Nymphaea tetragona*, *Pistia stratiotes*, agrotourism.

### INTRODUCTION

The irrigation water in villages in tropical countries is facing a reduction in water quality. It urgently needs to be concerned, so it can be effectively utilized as irrigation water for agriculture, aquaculture and potentially even household needs (Goyal et al., 2021). The rapid changes in land and water use due to dynamic farming intensity constitute the main factor affecting water quality and quantity, ecology, and biodiversity globally (Alavaisha et al., 2019). The community activities have expanded along the irrigation canal, such as laundering, washing or even bathing. Solid waste is also dumped in the channel and causes floods during the rainy season because of clogging with

plastics. The type of pollutants within domestic wastewater can significantly vary based on location and pollutant type (Abbasov & de Blois, 2021; Sumantra et al., 2022). Consequently, some chemicals from those activities are released and pollute the water body. Besides, the discharge of wastewater into the irrigation system is also an issue of a public health concern as the dormant odour and suitable breeding of any pathogen (Shukla et al., 2020; Wijaya & Soedjono, 2018b).

The main source of agricultural irrigation water comes from surface water. Due to the spatial difference in water content in wetlands, streams and rivers, assessment is necessary to provide robust insights into the quality and quantity of water that enter the paddy fields (Alavaisha et al.,

2019; Elias et al., 2014). Human activities around the paddy fields influence the nutrient input in the irrigation system, which leads to water physico-chemical conditions. The trophic state is defined by the factors that are related to nutrient contents, algae biomass and water transparency (Ayoade et al., 2019; Soedjono et al., 2018; Sumantra et al., 2022; I. Wijaya et al., 2017). It causes water quality deterioration due to the discharge of untreated wastewater from the municipality (Abou-Elela, 2019; Soedjono et al., 2018).

Therefore, pre-treatment is urgently needed before the irrigation water enters the paddy fields, using natural treatment process such as the constructed wetland. Agricultural practices have been developed using large amounts of chemical fertilizers and pesticides to sustain yields and productivity. This practice raised the level of nutrients reaching the aquifers, therefore contaminating the surface and groundwater (Aguilar et al., 2019). Constructed wetland (CW) is an engineered system that simulates processes from natural wetlands. With low external energy requirements, it improves water quality by means of a combination of physical, chemical, and biological processes (Ruiz, 2007). The last few years showed that artificial or constructed wetlands were frequently used to treat wastewater due to their low-cost operation and maintenance, low energy consumption and ease of operation (Aboukila & Elhawary, 2021). It consists of vegetation, substrates, microorganisms, and soil components to support the water treatment process (Abou-Elela, 2019; Wijaya & Soedjono, 2018a). Managing surface water pollution is critical for the economy, ecosystem, and human health concerns. CW can be installed in a pond that acts as a catchment area, flood controllers, and groundwater runoff. The CW has a role as trash trap and sedimentation storage so the water can be free of debris and sediment loads (Adek Rizaldi & Limantara, 2018). The present study aimed to examine candung as a local attached constructed wetland for treating irrigation water, with additional plants cultivation and analysing the community awareness regarding the candung application.

## METHODOLOGY

### Study location

The research was conducted in a local irrigation water community named Subak Lepud. It is

located in Baha Village, Badung Regency, Bali Island. It was supported by the Subak Lepud community and also farmers around the subak area. Candungs were built in the corner of each paddy fields area and connected to the irrigation water system along the paddy fields area. It is a 1×1 m area bordered by higher subsoil levels in order to maintain the water overflow. Within about 50 cm of depth, candung could receive and hold about 0.5 m<sup>3</sup> of water at a time. The solid content of irrigation water could be settled during the storage of candung. There were three water plants used in candung, such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*. Those plants are commonly used as decorative plants at home, in parks or gardens; meanwhile, in this research, they were used as emergent plants. The water will flow along the irrigation channel, enter candung, which is installed in the entrance and flow to the paddy field.

### Water quality sampling

The irrigation water samples were collected from 15–20 cm below the surface in the month of September 2021. Those were taken in candung box, which is placed right before the irrigation water enters the paddy fields. The water samples were taken at the upstream, midstream, and downstream points. Sample water was also taken from each candung box right after those stream points. There are three candung boxes at each point (upstream, midstream, downstream). Those candungs represent the different water plants mentioned above. Accordingly, 12 water samples have been analysed in this study. The samples were preserved and analysed for physico-chemical characteristics. Total dissolved solids (TDS) and total suspended solids (TSS) were measured by using filtration and gravimetric method. The accuracy of those methods is well documented in the scientific literature (Rahmanian et al., 2015). A 100 mL water sample was poured into weighed glass fibre filter of a specified pore size before starting the vacuum filtration. The filter was taken up after the completion of the filtration and placed in an aluminium dish in an oven at 100 °C for 2–3 hours to completely vaporize the remaining water. Afterwards, the filter paper was weighed, and the gain in filter weight showed the TSS contents in mass per volume of the filtered sample (mg/L). The TDS were determined by the gravimetric method. After filtration for TSS analysis,

the filtrate was placed in the oven at above 100 °C until all the water was totally evaporated. The remaining mass of the residue represents the TDS in the water sample. The chemical compound such as dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), ammonium and phosphate were measured according to the standard method (Apha/Awwa/Wef, 2012). The samples were measured in the Laboratory of Health of Bali Province in triplicate.

### Community responses questionnaire

A community perspective has been analysed through a questionnaire with five variables, such as knowledge, behaviour, action, perception, tourism potential and health food material. The knowledge variable is interpreted as the understanding of the Subak Lepud members towards candung and water plants on agricultural land. In this study, the knowledge variable was measured by six indicators, namely: (1) the benefits of candung and water plants for environmental preservation; (2) the impact that occurs if candung and water plants are not preserved; (3) the benefits of water plant species (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*) in aquatic ecosystems; (4) the impact of destroying and removing phytoremediation plant species from the environment; (5) the importance of conserving water plant species as phytoremediation/toxic absorbers; and (6) procedures for the preservation of candung and water plants.

The attitude variable is interpreted as the reaction of Subak Lepud members from their understanding of candung and water plants on agricultural land. In this study, the attitude variable was measured by five indicators, namely: (1) participating in conserving candung and water plants to maintain the balance of the ecosystem; (2) participating in conserving candung and water plants as an environmental conservation measure; (3) participating in conserving candung and water plants for subak irrigation which are polluted by waste; (4) taking part in maintaining the local wisdom of candung and water plants because it can improve the ecological and economic welfare of the community; and (5) participating in conserving water plant species as phytoremediation/toxic absorbers. The action variable is defined as the actions committed by members of the Subak Lepud against candung. In this study, the action

variable was measured by five indicators, namely: (1) not creating candung and planting water plants in candung; (2) not making candung and planting water plants so that the rice planting area is wider; (3) conserving candung and water plant species because they have important ecological functions that are beneficial; (4) planting water plants in candung (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*), because they have economic value; and (5) participating in the conservation of candung and water plants that absorb poisons/contaminants. The perception variable is interpreted as the views of Subak Lepud members regarding the benefits of candung on agricultural land. The perception variable is measured by five indicators, namely: (1) the sustainability of candung and water plants can be beneficial for the balance of aquatic ecosystems; (2) the benefits of candung and water plants in maintaining and improving water quality; (3) the benefits of candung and water plant species for organisms that live in rice fields; (4) the benefits of preserving candung and water plants to overcome water pollution that enters rice fields; and (5) the benefits of conserving candung and water plants for the community.

The variable of the potential for educational tourist attractions is interpreted as the views of Subak Lepud members regarding the potential of candung and water plants on agricultural land as educational tourist attractions and healthy food providers. In this study, the variable of the potential of educational tourist attractions was measured by five indicators, namely: (1) candung and water plants (such as *Nelumbo nucifera*, *Nymphaea tetragona*) have subak local wisdom values; (2) candung and water plants that absorb pollutants (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*) will be able to produce healthy food products; (3) candung and pollutant-absorbing water plants (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*) can be used as educational tourist attractions; (4) support from subak members in the conservation of candung and water plants (such as *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*); and (5) a district/provincial government policy is needed for the conversation of candung and water plants as educational tourist attractions.

Inferential analysis was carried out by using Path Analysis with the help of the Smart-PLS program. The analysis was first performed

to evaluate the structural model by taking into account the  $Q^2$  predictive relevance model. The goal was to measure how well the observed values were generated by the model.  $Q^2$  is based on the coefficient of determination of all dependent variables. The value of  $Q^2$  has a range of  $0 < Q^2 < 1$ , the closer to 1, the better the model. In this structural model, there are three endogenous (dependent) variables, namely: Perception, Action and Potential, so three coefficients of determination ( $R^2$ ) can be determined, which are the basis for calculating the  $Q^2$  predictive relevance model.

To obtain data that has good calibration for each of the variables studied, the research instrument needs to be tested for its validity and reliability. Thus, it is important to carry out tests to ensure the level of validity and reliability of the research instrument is in accordance with the specified criteria. Testing the research instrument was carried out by means of a trial (pre-research) by distributing 35 questionnaires to Subak Lepud members. The validity test aims to measure whether the research instrument is valid or not. The research instrument is said to be valid if the

instrument is able to accurately measure what is to be measured (Ghozali, 2009). Testing the validity of this instrument uses the validity of the criteria calculated through corrected item correlation analysis. Through this analysis, the research instrument is said to be valid if it has a correlation coefficient above 0.30. Meanwhile, the reliability test aims to measure the internal consistency of an indicator of a variable. High-reliability results provide confidence that all individual indicators are consistent with their measurements (Wijanto, 2008). This reliability test uses the one-shot method or is done only once, which is measured using Cronbach Alpha ( $\alpha$ ) analysis. A variable is said to be reliable if it has a Cronbach Alpha ( $\alpha$ ) value above 0.60 (Nunally, 1960 in Ghozali, 2009). The results of testing the research instrument from the questionnaire trial ( $n = 35$  samples) that was carried out can be presented in Table 1.

The information from Table 1 shows that all statement items from five variables, namely knowledge, experience, intention, action and potential were valid (correlation coefficient was above 0.30) and showed a good level of reliability

**Table 1.** Recapitulation of research instrument testing results

No	Variable	Item	Validity test (koef. r)	Reliability test (koef. Cronbach Alpha)
1.	Knowledge	Know <sub>1</sub>	0.915	0.982
		Know <sub>2</sub>	0.963	
		Know <sub>3</sub>	0.970	
		Know <sub>4</sub>	0.931	
		Know <sub>5</sub>	0.970	
2.	Experience	Exp <sub>1</sub>	0.942	0.933
		Exp <sub>2</sub>	0.727	
		Exp <sub>3</sub>	0.947	
		Exp <sub>4</sub>	0.781	
3.	Intention	Intent <sub>1</sub>	0.934	0.964
		Intent <sub>2</sub>	0.858	
		Intent <sub>3</sub>	0.943	
		Intent <sub>4</sub>	0.819	
		Intent <sub>5</sub>	0.966	
4.	Action	Act <sub>1</sub>	0.742	0.945
		Act <sub>2</sub>	0.865	
		Act <sub>3</sub>	0.929	
		Act <sub>4</sub>	0.913	
		Act <sub>5</sub>	0.821	
5.	Potential	Pot <sub>1</sub>	0.743	0.943
		Pot <sub>2</sub>	0.881	
		Pot <sub>3</sub>	0.914	
		Pot <sub>4</sub>	0.802	
		Pot <sub>5</sub>	0.904	

(Cronbach's Alpha correlation coefficient ( $\alpha$ ) was above 0.60). Thus, the research instrument (questionnaire) could be used and distributed to all predetermined target samples. The data collected was 182 units out of 200 units which were distributed to all members of Subak Lepud. The results of the further examination showed that the 182 data units had been filled in completely, so they were ready for further analysis.

## RESULTS AND DISCUSSION

### Candung as a locally appropriate technology

The silt that may be drifted along the irrigation system needs to be removed in a sedimentation chamber before entering the paddy fields. This candung will help reduce the clogging irrigation system as well as eliminate a large part of the particulate organic load and forms of nutrients entering ponds. The candung pool is shallow and sealed around to maintain the overflow. Soil is the main substrate of candung with thickness up to 50 cm and thus, it allows the formation of wetland plants (Abou-Elela, 2019). According to Kadlec (Kadlec & Wallace, 2008), there are four main principles of constructed wetlands, including candung. They are balancing the conversion rate of natural wetlands resulting from agriculture and urban development, improving the water quality after the treatment, flood control and supporting food production. Candung can be considered as part of the wastewater treatment system to provide physical and biological treatment. Vegetation, substrates, soils, microbes, and water are the essential components of the technique. To remove various contaminants, it employs complex processes involving physical, chemical, and biological mechanisms (Abou-Elela, 2019). The wastewater treatment in candung is commonly practiced through biological processes (like microbial activity and plant uptake) and physico-chemical processes (like precipitation, adsorption, and sedimentation) (Biswas et al., 2021). As a system, candung belongs to a free water surface constructed wetland (FWSF) which operates like a natural wetland. One of the important parts of candung is the emergent plants which have several purposes and be mutual with the microorganism. The stems and submerged leaves support the growth of bacteria, and the leaves above the surface shade the water as well as reduce the potential

for rapid algae growth, whereas oxygen from the atmosphere is transported from the leaves down to the roots, which supports the plant growth.

Constructed wetlands (CWs) for wastewater treatment are a natural, simple, low construction and maintenance cost, and environmentally friendly method, representing alternative and promising solutions for environmental protection and preservation. CWs are most suitable for small areas and rural communities (Abbasi et al., 2019). Water and nutrient recycling are emerging and part of water management. Proper wastewater treatment is an issue in sustainable development related to water demand and designed due to growing populations, whereas global climatic changes have increased water stress conditions, especially in limited water resource areas (Bargallo et al., 2014). In constructed wetland systems, plants can play an important role in the removal of nutrients from wastewater compared to unplanted wetlands. Macrophytes can improve wastewater quality by helping to settle suspended solids, directly taking up nutrients, and providing support for microbial flora (Lin et al., 2002).

Therefore, the seasonal selection of plants for constructed wetlands should be an important part of wastewater treatment management in a CW system. Most of the previous research on constructed wetlands covered one plant season, but the period of vegetative growth followed, culminating in death. After completion of a life cycle, plants leave, roots begin to die, and if plants remain in the CW, decay from the plant material will release nutrients back to the CW. Therefore, appropriate plants for the specific season will optimize the function of the constructed wetland.

### Treatment ability of candung

*The pH, total suspended solid (TSS), and total dissolved solid (TDS)*

The pH is one of the important water quality characteristics that represent the acidity or alkalinity of the water sample. A pH below 7.0 is considered acid, while the pH above 7.0 is alkaline (Sawyer et al., 2003). The hydrogen-ion concentration is very important to speed up the biochemical process, which is also depending on the current enzyme. The enzyme sometimes needs a certain pH value to achieve the best reaction rather than a lower pH or higher pH. The pH affects the suitability of available water to



support the living organism (Qasim, 1999; Tcho-banoglous et al., 2002). Acidic water can affect the corrosion of metal; meanwhile, alkaline is presenting disinfection of the water. The normal drinking water pH range is around 6.5–8.5 (World Health Organisation (WHO), 2017). The pH in the 12 water samples showed a pH range between 7.0–8.0. The lowest pH was found at the upstream point with 7.39; meanwhile, the highest one was found at the downstream point after the candung with *Nymphaea tetragona*. According to the pH analysis, the pH value from the upstream to the downstream increased from 7.39 to 7.88.

After passing through the candung, there were some changes to the pH value. After the upstream, the pH value of the effluent of candung with *Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes* was 7.42; 7.64; 7.43, respectively. In the mid-stream, the pH was measured at 7.71; 7.75; 7.71, respectively, for three candungs; meanwhile, the downstream were 7.93; 7.81; and 7.79. All the pH values of those effluents were

covered by the national pH threshold of 6-9. According to Amic and Tadic (Amić & Tadić, 2018), the pH value of various stream water environments is in the range of 6.5 to 8.5, while pH below 4 (acid) and above 10 (base) creates a damaging living environment. The pH trend of the effluent is shown on Figure 1.

The presence of various solid particles, whether suspended or dissolved, is characterized by the physical water quality (Soedjono et al., 2018; Wijaya & Soedjono, 2018). The solid shows the amount of particle or slurry left when the water is totally removed. The total solid is the content of solid in a sample after the sample has been dried at over 100 °C for 24 hours and compared to the original mass of the sample. Total dissolved solids (TDS) is the sample that only can appear under dry conditions, while total suspended solids (TSS) still remain intact when placed into the water (Hamilton & Zhang, 2003; Ramesh & Jain, 2017). Total solid is represented by the sum of TDS and TSS. Water with a high

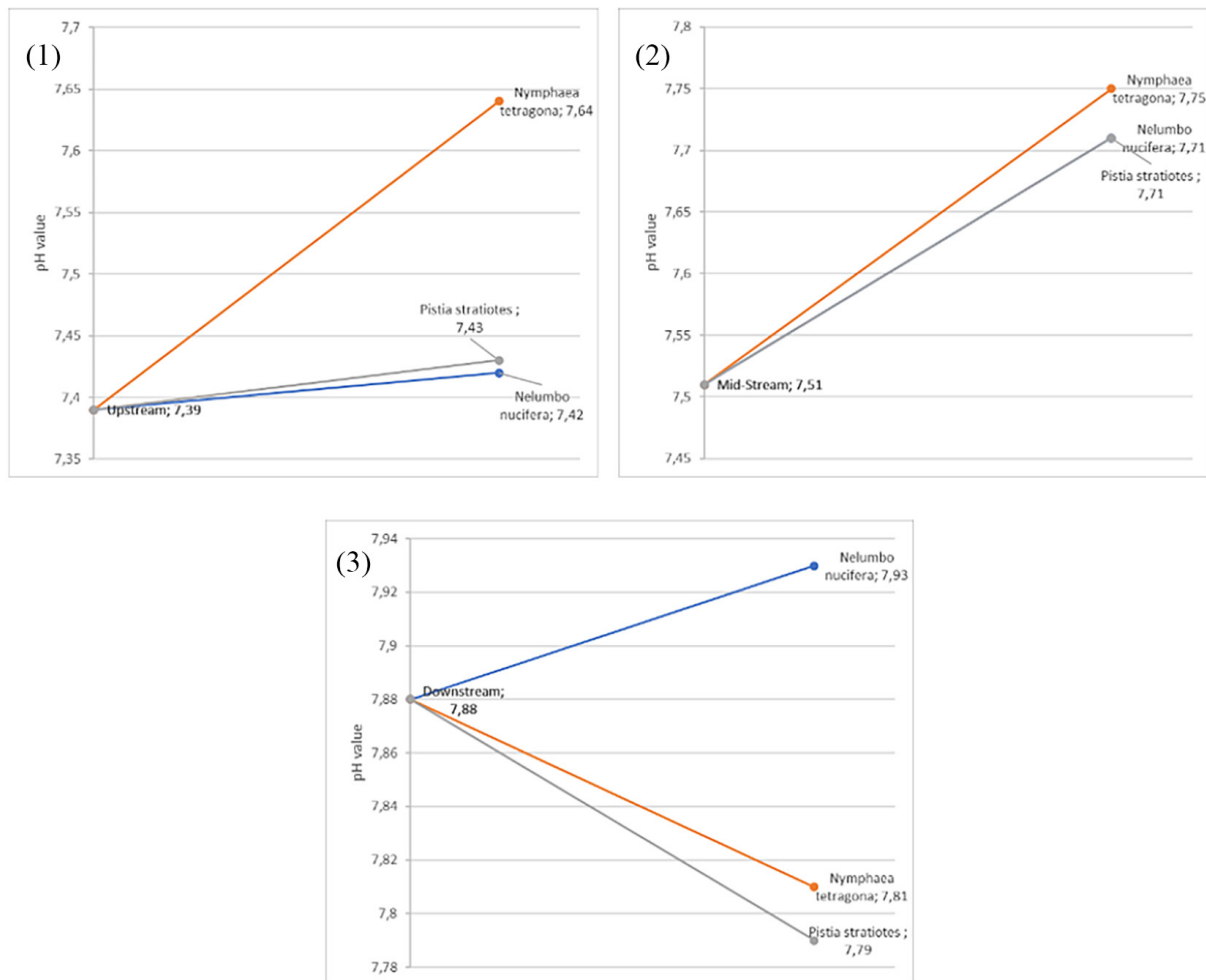


Figure 1. The pH value in each effluent of candung from upstream (1), mid-stream (2) and downstream (3)

dissolved solid concentration has an adverse impact on irrigation crops and plants; meanwhile, the highly suspended solid can cause a scum layer (floating solid) or build-up sediment (sink solid) (Ayoade et al., 2019; M. Faisal et al., 2015). The limits of TSS and TDS according to the national water quality standard for class II are 50 mg/L and 1000 mg/L, respectively. The TSS concentration increased from the upstream to the downstream due to the wastewater discharged along the stream.

The TSS measurement showed various changes in the TSS concentration in the effluents after passing through candung. At the upstream point, the TSS of effluent increased after candung with *Nelumbo nucifera* and *Pistia stratiotes* with 85 mg/L and 59 mg/L, respectively. There was no change of TSS after candung with *Nymphaea tetragona* at 39 mg/L. TSS contributes to the sediment in the water body and potentially causes oxygen depletion. It is important to control the treatment process following the effluent

regulation (Hudson, 2010; Wijaya et al., 2019). According to the national water quality standard classification (*Peraturan Pemerintah Republik Indonesia Nomor 82 Tahun 2001 Tentang Pengelolaan Kualitas Air Dan Pengendalian Pencemaran Air*, 2001), those concentrations were out of Class II water quality and belonged to Class III. The effluent TSS from candung at the mid-stream and downstream has declined for all plants. The decreasing TSS indicates that the plants have promoted the solid to settle down as sediment. The highest removal of TSS was found in the mid-stream and downstream's candung for *Nelumbo nucifera* (60.34%) and *Pistia stratiotes* (63.75%), respectively. The TSS concentration from the upstream, midstream, and downstream can be seen in Figure 2.

Total dissolved solids (TDS) indicate the dissolved salt in the water sample out of the suspended solid (SS). The TDS concentration is related to electrical conductivity or conductance. It shows the ability of water to transmit an electrical

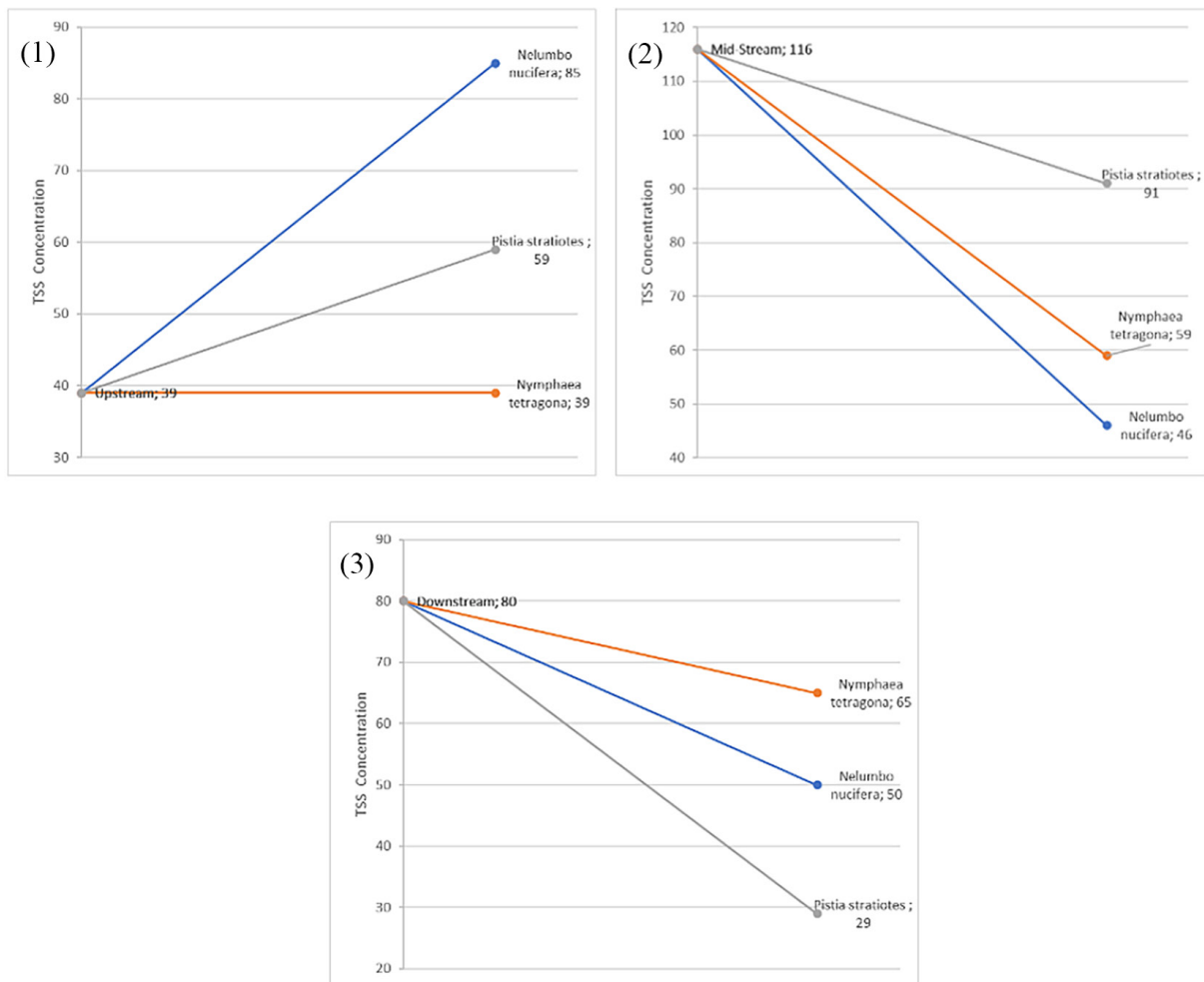


Figure 2. The TSS concentration in each effluent of candung from upstream (1), mid-stream (2) and downstream (3)

current that increases as the TDS concentration increases (Larrarte & Pons, 2011; Ramesh & Jain, 2017). TDS consists of various inorganic salts, such as sodium (Na<sup>+</sup>), calcium (Ca<sup>+</sup>), magnesium (Mg<sup>+</sup>), potassium (K<sup>+</sup>), chloride (Cl<sup>-</sup>), nitrates (NO<sup>3-</sup>), and bicarbonates (HCO<sup>3-</sup>). According to World Health Organization (WHO) standard for water quality, the permissible TDS for agriculture is in the range of 450–2000 mg/L (Jamei et al., 2020). In a stream and rivers, the conductivity capacity is altered by various factors, such as soil type, rock type, and the presence of dissolved solids (Vadde et al., 2018). TDS consists of ionic constituents that conduct electricity. TDS and bulk conductivities of sediment in the water body are generally higher at contaminated locations (Atekwana et al., 2004). Water with high TDS has been known to cause a detrimental effect on organism's health due to its adverse effect on feedstock (Sharma et al., 2017). A study from Devesa and Dietrich (Devesa & Dietrich, 2018) stated that the TDS also could represent the mineral content in the water body and

affect the taste of the water. It can be considered with a concentration of TDS>150 mg/L. The TDS analysis in this study showed that the TDS concentration was very low under the national water quality standard classification (*Peraturan Pemerintah Republik Indonesia Nomor 82 Tahun 2001 Tentang Pengelolaan Kualitas Air Dan Pengendalian Pencemaran Air*, 2001), which is 1000 mg/L.

TDS in the upstream point was measured at 138.9 mg/L, while in the mid-stream and downstream was 133 mg/L and 127 mg/L, respectively. Candung has no significant effect on the TDS concentration after the water passes it through. The lowest TDS concentration from the candung was found at the mid-stream point after candung with *Nymphaea tetragona*, which was 119,5 mg/L. A low TDS is also found in the study by Mazood et al. (Mazood et al., 2023), which is in a range of 99.6–101.2 mg/L with a standard value in the range of 400–500 mg/L. The decline of TDS concentration after all candungs is presented in Figure 3.

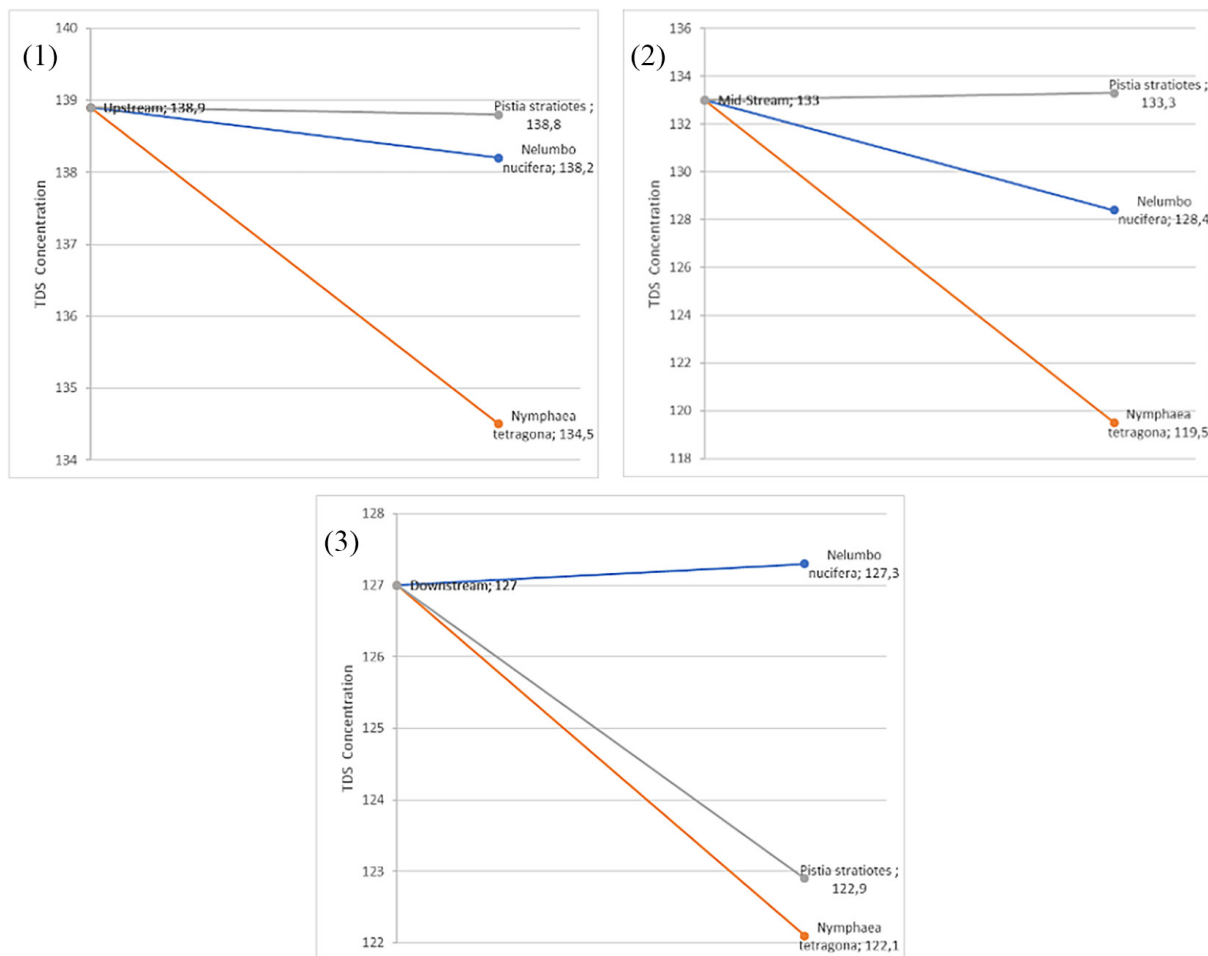


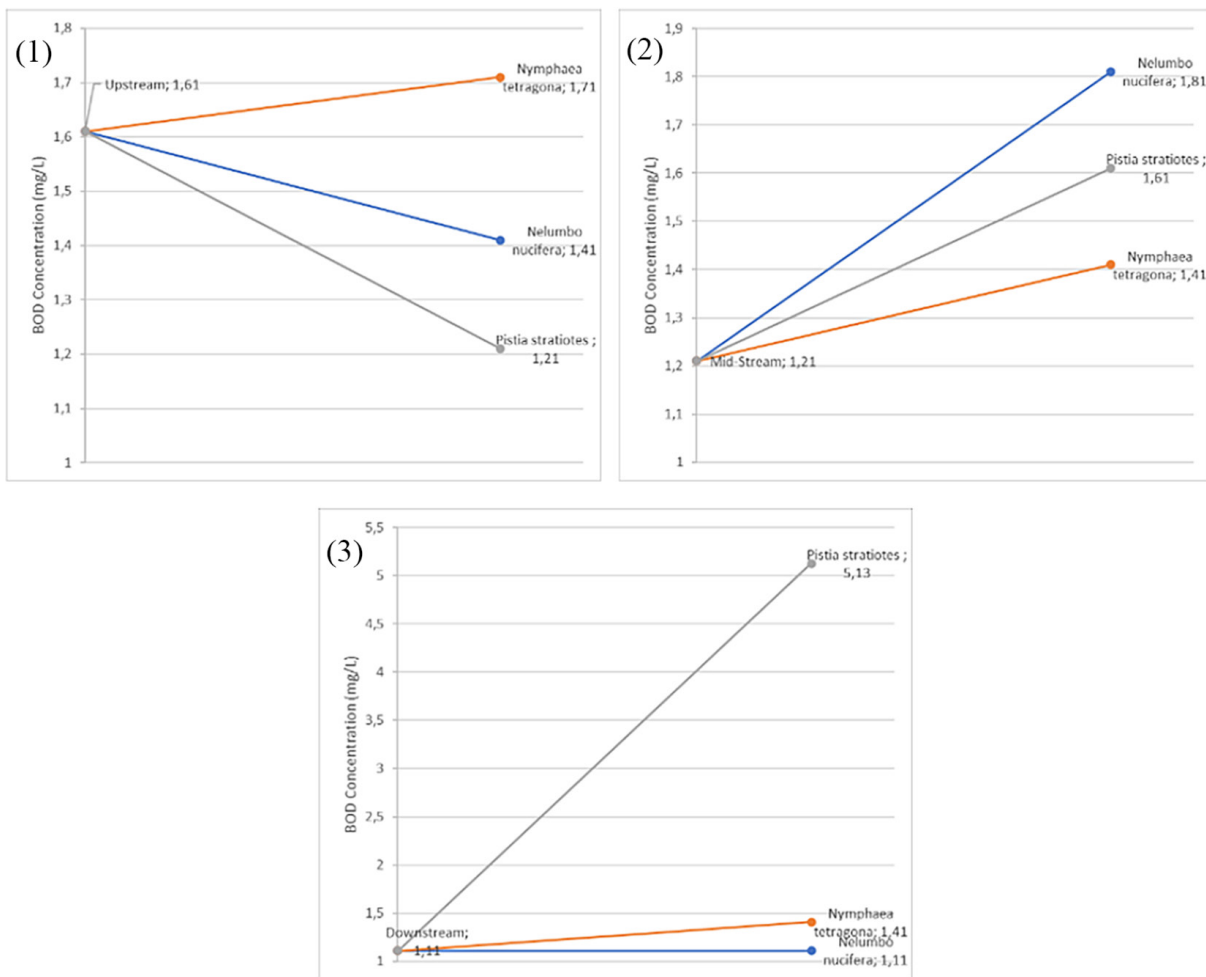
Figure 3. The TDS concentration in each effluent of candung from upstream (1), mid-stream (2) and downstream (3)

**Biological oxygen demand (BOD)**

An enormous BOD concentration in the water body damages the water quality. It causes a low dissolved oxygen (DO) condition and an unfavourable life environment for the aquatic organism. BOD and DO have an exchange relationship with the riverbed, nitrification and denitrification (Koklu, 2009). BOD represents the total oxygen consumption to break down the organic material, which is performed by aerobic biological microorganisms (Faisal et al., 2020; Gu et al., 2013). It provides the information about available biodegradable fraction which is loaded in the water (Jouanneau et al., 2013). The decrease in BOD is possibly caused by the oxidation of organic matter, which provides the energy resource for the microorganism metabolic process and is synthesized into cell mass (Marcato et al., n.d.). BOD is a commonly used parameter for assessing the biodegradability of dissolved organic matter in water bodies (Simon et al., 2011).

The aerobic microbiological degradation and sedimentation/filtration processes are the primary

causes of BOD decrease. In subsurface flow wetlands, organic molecules can be destroyed both aerobically and anaerobically. Atmospheric oxygen diffusion, convection (wind effect), and/or macrophyte root transfer into the plant rhizosphere can provide oxygen for aerobic breakdown. Without oxygen, anaerobic organic elimination might take place inside the media pores. Anaerobic degradation is a two-step process undertaken by anaerobic heterotrophic bacteria in wetlands. Acid-forming bacteria synthesize organic materials into new cells, organic acids, and alcohols in the first phase (fermentation). Methane-forming bacteria, in the second stage, continue the oxidation (methanogenesis) by turning organic molecules into new bacterial cells, methane, and carbon dioxide. In the anaerobic zones of wetlands, fermentation and methanogenesis occur (Abedi & Mojiri, 2019; Kadlec & Wallace, 2008). The BOD concentration from the upstream is in the range of 1–5 mg/L (Figure 4), which belongs to the water class I-III according to the national water quality standard (PP No.8/2001). BOD was classified as low BOD



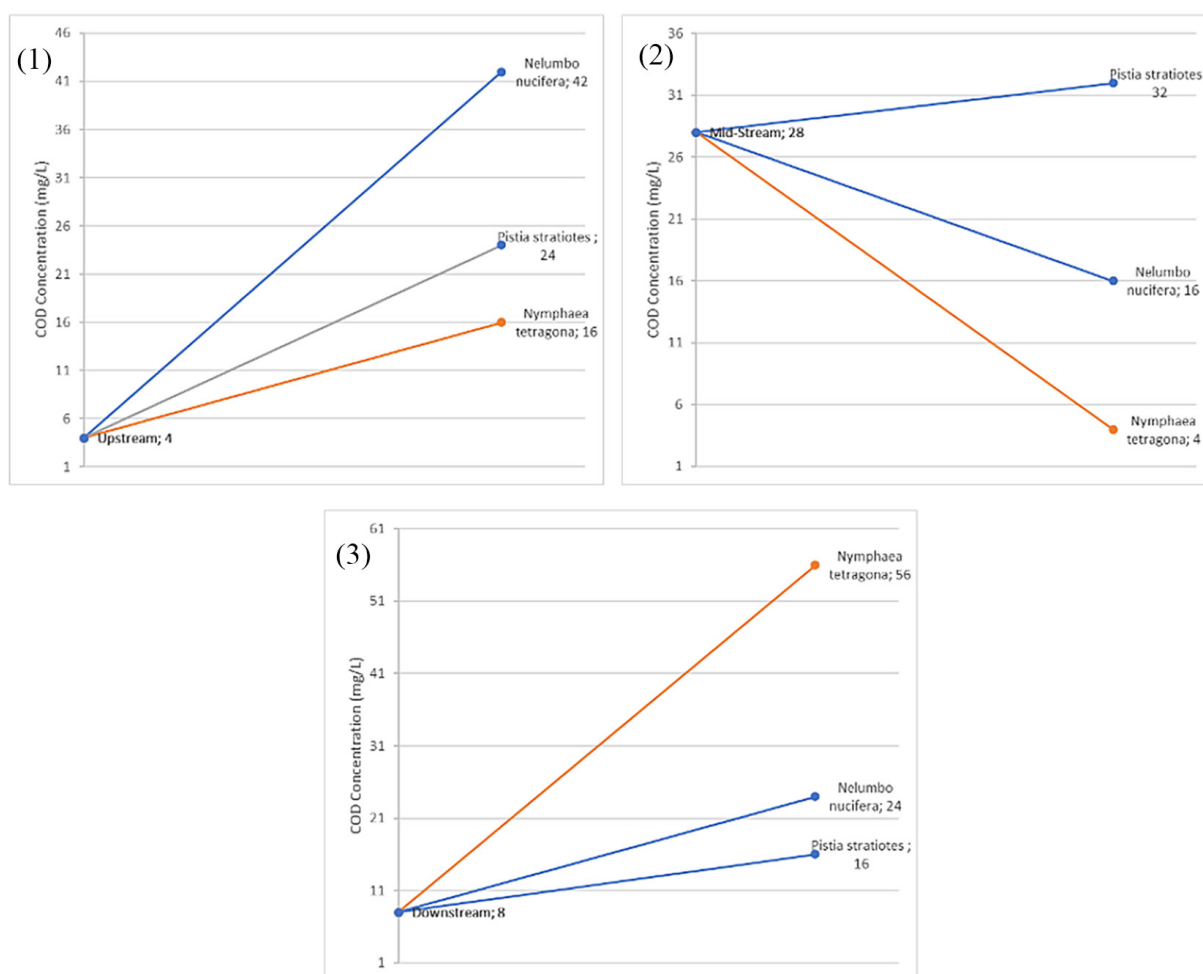
**Figure 4.** The BOD concentration in each effluent of candung from upstream (1), mid-stream (2) and downstream (3)

concentration in all streams. In the upstream, the BOD was measured at 1.61 mg/L; in the mid-stream was 1.21 mg/L and in the downstream was 1.11 mg/L. The BOD decreased from the upstream to the downstream, which indicates the removal along the stream. The role of water plants has shown the changes of BOD in the stream water. The lowest BOD concentration was found in candung upstream area with *Pistia stratiotes* with 1.21 mg/L. In the midstream, the BOD was found to increase to 1.81 mg/L in candung with *Nelumbo nucifera*, and in the downstream, there were significant changes of the BOD in candung with *Pistia stratiotes* with 5.13 mg/L. The increase in BOD indicates that more dissolved oxygen in the stream is depleted. It could be caused by the settlement of debris, leaves, woods, dead plants and animal that becomes biomass and carbon sources.

**Chemical oxygen demand (COD)**

COD is described as the number of oxygen equivalents used in oxidizing the organic matter

of samples by strong oxidizer agents such as dichromate or permanganate. The higher the chemical oxygen demand, the greater the concentration of pollution in the water sample (G. H. Faisal et al., 2020). COD is considered one of the most important water quality parameters of wastewater. The typical BOD/COD ratio for untreated household wastewater is 0.3–0.8; a BOD/COD ratio of 0.5 or above indicates that the available organics are easily degradable by microbes, whilst a ratio below 0.3 indicates that the available organics are harder to break down by microorganisms (Kadlec & Wallace, 2008). According to the results of COD concentration after passing through each candung, the effluent of candung at the upstream and downstream gave negative results or significantly increased the COD. The BOD/COD ratio was found very low in all water sources (upstream, middle stream and downstream), below the threshold value to provide a proper environment for the microorganism, which is at least 0.5 or above. It results in low organic removal



**Figure 5.** The COD concentration in each effluent of candung from upstream (1), mid-stream (2) and downstream (3)

**Table 2.** The BOD/COD ratio of each stream and candung

Parameter	Raw water	<i>Nelumbo nucifera</i>	<i>Nymphaea tetragona</i>	<i>Pistia stratiotes</i>
Upstream	0.40	0.03	0.11	0.05
Mid-Stream	0.04	0.11	0.35	0.05
Downstream	0.14	0.05	0.03	0.32

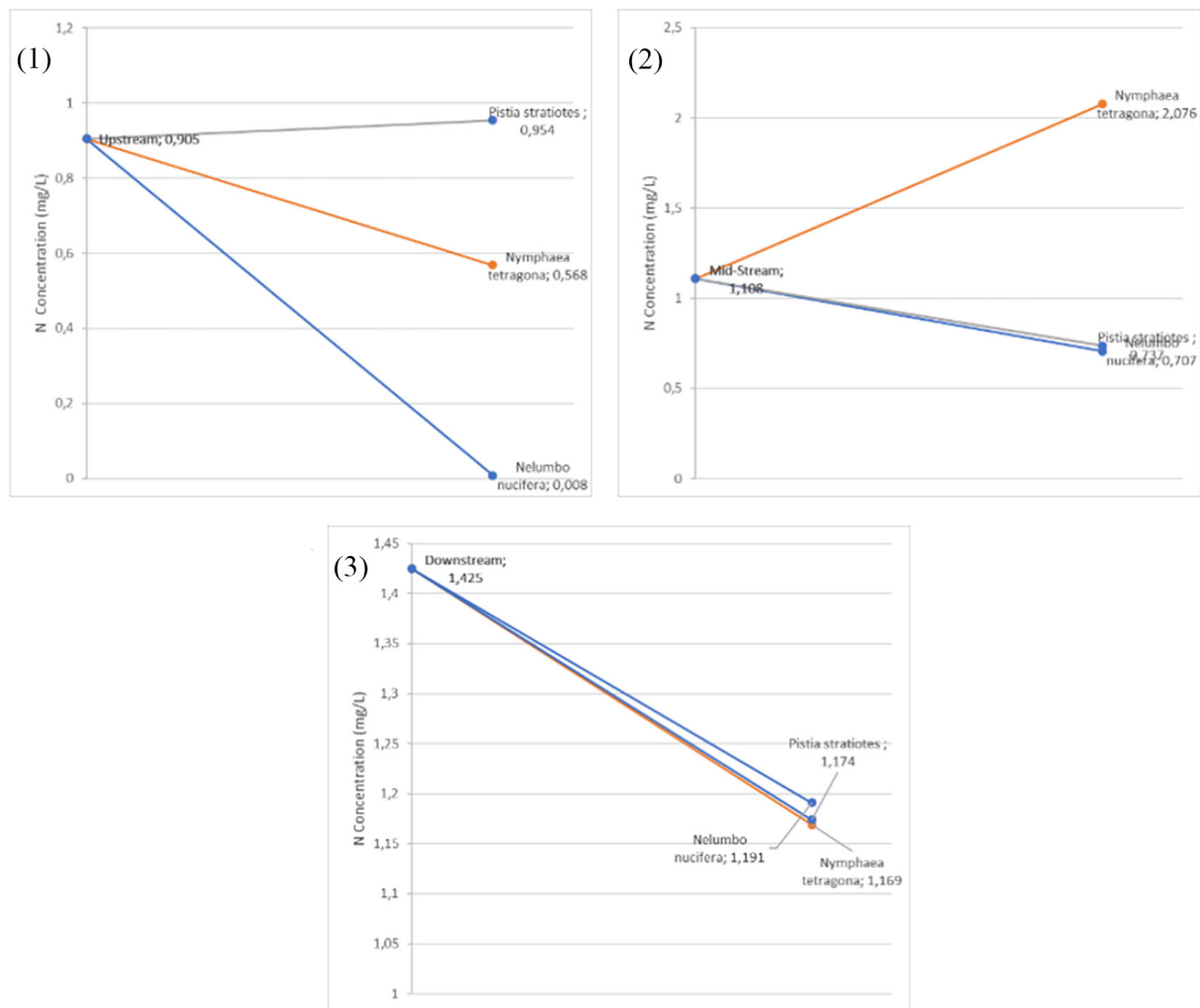
percentages because of the decrease in microbial activities to degrade the organic matter. A low BOD/COD ratio gives more insight into the COD concentration, whereas the organic matter that has to be degraded with chemical oxidants, such as potassium dichromate, is higher than the biodegradable (BOD). Besides, the presence of humic material in candung also contributes to the higher COD concentration. Humic substances contain carbon, hydrogen, oxygen, nitrogen and small amounts of sulphur and phosphorus. The humic substances contained in products are commonly used in agriculture as part of the fertilizer, but on the other side, their rise is also a sign of organic pollutant levels, colour intensity, and chemical activities in the water (Rupiasih, 2016). The trend of COD concentration in the effluent of candung is presented on the Figure 5 and the the ratio of BOD/COD on the Table 2.

#### Nutrient content

The most important organic forms of nitrogen in constructed wetlands are ammonium ( $\text{NH}_4^+$ ), nitrite ( $\text{NO}_2^-$ ), and nitrate ( $\text{NO}_3^-$ ). Gaseous nitrogen can be present as dinitrogen ( $\text{N}_2$ ), nitrous oxide ( $\text{N}_2\text{O}$ ), nitrous oxide ( $\text{NO}_2$  and  $\text{N}_2\text{O}_4$ ), and ammonia ( $\text{NH}_3$ ). Various forms of nitrogen are always involved in the chemical conversion of inorganic compounds to organic compounds and from organic compounds to inorganic compounds (Abba et al., 2021). Some of these processes require energy (usually from an organic carbon source) to continue, while others release the energy that the organism uses for growth and survival. All of these transformations are necessary for the normal functioning of wetland ecosystems, and most chemical changes are facilitated by the production of enzymes and catalysts by organisms that benefit them (Vymazal, 2007). Ammonia is converted from its organic form through a complex, energy-releasing, multi-step biochemical process. In some cases, this energy is used by the microorganisms for growth and ammonia is incorporated directly into the microbial biomass. Nitrogen assimilation refers to various biological processes that convert inorganic forms

of nitrogen into organic compounds that function as components of cells and tissues. The two forms of nitrogen commonly used for assimilation are ammonia and nitrogen nitrate. Ammonia nitrogen is a suitable nitrogen source for assimilation because it is reduced more energetically than nitrate. Ionized ammonia can be adsorbed from solution by cation exchange reactions with detritus, inorganic deposits, or soil. The adsorbed ammonia is loosely bound to the substrate and is easily released when the hydrochemical conditions change (Ribeiro et al., 2022). At a given concentration of ammonia in the water column, a certain amount of ammonia is adsorbed and saturated at the available binding sites. When the concentration of ammonia in the water column decreases, some of the ammonia desorbs and re-balances with the new concentration. The higher the ammonia concentration in the water column, the more ammonia is adsorbed. When wetland substrates are exposed to oxygen, perhaps due to regular aeration, the adsorbed ammonium can be oxidized to nitrate. Ammonium ions ( $\text{NH}_4^+$ ) are generally adsorbed on clay as exchangeable ions and are chemically adsorbed by humic substances or fixed to the clay lattice. It seems that these reactions can occur at the same time.

According to ammonium concentration analysis, it was found that the ammonium concentration was increasing from the upstream to downstream. In the upstream, the candung with *Nelumbo nucifera* showed the best result with 99.11% removal of ammonium; meanwhile, the candung with *Nymphaea tetragona* had 33.23% removal, but after the candung with *Pistia stratiotes* had a negative result, which was higher than the influent. In the mid-stream, candung with *Nelumbo nucifera* and *Pistia stratiotes* has a similar result on ammonium removal, about 33%-36%. In the downstream, the ammonium concentration was found at 1.911 mg/L (*Nelumbo nucifera*), 1.169 mg/L (*Nymphaea tetragona*), 1.174 mg/L (*Pistia stratiotes*) with the range of ammonium removal 16–17%. The candung with *Nelumbo nucifera* gave the best result in all three stream areas. The trend of nitrogen concentration in the effluent is shown on the Figure 6.



**Figure 6.** The nitrogen concentration in each effluent of candung from upstream (1), mid-stream (2) and downstream (3)

### Community responses on the application of candung to maintain the irrigation water

#### Respondent demographic

The results of the descriptive analysis of the demographics of the respondents aim to obtain an overview of the respondent’s profile regarding age, education level, and land area. The results of the analysis obtained for the demographics of the respondents can be presented in Table 3.

Table 3 shows the demographics of respondents based on age, showing more respondents over 50 years with a distribution of 86.3%. Furthermore, it was followed by the respondents of 40–49 years (11.5%), 30–39 years (1.6%), and under 30 years (0.5%). The information from the distribution of respondents by age indicates that most of the members of Subak Lepud are old enough to work on the land they own.

In terms of respondent demographics based on education level (Table 3), Subak Lepud

members dominantly have senior high school/ equivalent education, namely 45.1%, followed by those with junior high school education (25.3%), elementary school (18.1%), and the least, bachelor’s degree (11.5%). This information illustrates that the level of education of Subak Lepud members is still very low because the majority are below bachelor’s degree, namely 96.6%. On the basis of this information, the members of Subak Lepud are still working on their agricultural land in the traditional way.

In terms of land ownership (Table 3), Subak Lepud members dominantly own more than 34 acres (36.3%) of land to cultivate. Next, followed by arable land ownership of 20–24 acres (17.6%), 30–34 acres (14.8%), 25–29 acres (14.3%), under 15 acres (10.4%), and the least, 15–19 acres (6.6%). On the basis of this information, it can be said that the land cultivated by Subak Lepud members is quite extensive. This descriptive analysis was carried out to find out the description of

**Table 3.** Respondent demographics

Number	Description	Number of People	Percentage (%)
1	Age		
	< 30 years	1 person	0.5
	30–39 years	3 people	1.6
	40–49 years	21 people	11.5
	50–59 years	88 people	48.4
	> 59 years	69 people	37.9
2	Education level		
	Elementary school	33 people	18.1
	Junior high school	46 people	25.3
	Senior high school/equivalent	82 people	45.1
	Bachelor's degree	21 people	11.5
3	Land area		
	< 15 acres	19 people	10.4
	15–19 acres	12 people	6.6
	20–24 acres	32 people	17.6
	25–29 acres	26 people	14.3
	30–34 acres	27 people	14.8
	> 34 acres	66 people	36.3
Total		182 people	100

the respondents' responses regarding the statements in the research instrument, especially the variables studied. The analysis was conducted by calculating the average (mean) based on the percentage of respondents' responses to each indicator in the research variables, namely: knowledge (know), experience (exp), intention (intent), action (act), and potential (pot). The higher the average value obtained, the better the respondent's response to the indicator or variable.

#### Community knowledge

The knowledge variable is defined as the understanding that Subak Lepud members have of the functions and benefits of candung and water plants on agricultural land. In this study, the variable knowledge is measured by five indicators, namely: (1) the function of improving water

quality (know1); (2) the function of increasing land quality (know2); (3) the benefit of increasing biodiversity (know3); (4) the benefit of improving the quality of food products (know4); and (5) the benefit of reducing the use of pesticides (know5). The description of the knowledge variable of Subak Lepud members can be presented in Table 4.

From the information in Table 4 above, it appears that the knowledge of Subak Lepud members regarding candung and water plants on agricultural land was still relatively limited or lacking, considering the average perception obtained was 2.36. Other information that can be conveyed is that members of Subak Lepud understood the function of candung and water plants to improve water quality because they had the highest average compared to other indicators (2.49). Meanwhile, the benefits of candung and water plants for

**Table 4.** Description of respondents on knowledge variable (know)

1	Description	Response (%)					Average (mean)
		1	2	3	4	5	
1	The function of improving water quality (know1)	25.8	28.0	19.8	24.2	2.2	2.49
2	The function of increasing land quality (know2)	25.8	30.2	23.6	18.1	2.2	2.41
3	The benefit of increasing biodiversity (know3)	25.8	32.4	26.9	14.8	-	2.31
4	The benefit of improving the quality of food products (know4)	25.8	36.8	19.2	18.1	-	2.30
5	The benefit of reducing the use of pesticides (know5)	25.8	34.6	23.1	16.5	-	2.30
Knowledge variable (know)							2.36



**Table 5.** Description of respondents on experience variable (Exp)

Description		Response (%)					Average (mean)
		1	2	3	4	5	
1	The use to reduce waste pollution (exp1)	9.9	9.9	59.3	18.7	2.2	2.93
2	The use as a medium for absorbing toxic in the field (exp2)	9.9	9.9	57.1	23.1	-	2.93
3	The use to maintain the balance of the land ecosystem (exp3)	9.9	9.9	59.3	20.9	-	2.91
4	The use to produce healthy rice (exp4)	9.9	9.9	59.3	20.9	-	2.91
Experience variable (Exp)							2.92

improving the quality of food products and reducing the use of pesticides were the lowest known to members of Subak Lepud, because they obtained the lowest average, which was equal to 2.30.

#### Community experience

The experience variable is interpreted as the experience felt by Subak Lepud members in utilizing candung and water plants on agricultural land. In this study, the experience variable (exp) is measured by four indicators, namely: (1) the use to reduce waste pollution (exp1); (2) the use as a medium for absorbing toxic in the field (exp2); (3) the use to maintain the balance of the land ecosystem (exp3); and (4) the use to produce healthy rice (exp4). The description of the experience variable (exp) of Subak Lepud members can be presented in Table 5.

On the basis of the explanation in Table 5, the experience of Subak Lepud members regarding the use of candung and water plants on agricultural land was still relatively low, considering the average perception obtained was 2.92. In other words, Subak Lepud members did not take advantage of the application of candung and water plants on cultivated agricultural land. Other information that can be conveyed is the experience of using candung and water plants to reduce waste pollution and toxic absorbing media on land tended to be practised by Subak Lepud members, because they obtained an average that was equally greater than the other indicators (2.93).

#### Community intention

The intention variable in this study is defined as the desire or interest of Subak Lepud members to cultivate candung and water plants on agricultural land. In this study, the variable intention (intent) is measured by five indicators, namely: (1) interest in cultivation (intent1); (2) interest in preservation (intent2); (3) plan of use (intent3); (4) inviting other fellows (intent4); and (5) socialization of use (intent5). The description of the intention variable of Subak Lepud members can be presented in Table 6.

From Table 6, it appears that Subak Lepud members tended to be interested in using candung and water plants on cultivated agricultural land with consideration of the average perception obtained at 3.17. Other information that can be conveyed is that the cultivation of candung and water plants tended to be of interest to members of Subak Lepud because it obtained the highest average, namely, 3.19. Meanwhile, members of Subak Lepud were of very little interest in preserving and planning the use of candung and water plants because they had the lowest average score, which was 3.15.

#### Community action

The action variable (act) is interpreted as the reaction of Subak Lepud members to cultivate candung and water plants on agricultural land. In this study, the action variable (act) was measured

**Table 6.** Description of respondents on intention variable (Intent)

Description		Response (%)					Average (mean)
		1	2	3	4	5	
1	Interest in cultivation (intent1)	3.3	1.6	69.8	23.1	2.2	3.19
2	Interest in preservation (intent2)	3.3	1.6	72.0	23.1	-	3.15
3	Plan of use (intent3)	3.3	1.6	72.0	23.1	-	3.15
4	Inviting other fellows (intent4)	3.3	1.6	69.8	25.3	-	3.17
5	Socialization of use (intent5)	3.3	1.6	69.8	25.3	-	3.17
Intention variable (intent)							3.17

by five indicators, namely: (1) the construction of candung and water plants at the inlet water (act1); (2) the construction of candung and water plants together with all subak members (act2); (3) the selection of candung and water plants that effectively absorb pollutants (act3); (4) the cultivation of candung and water plants with economic value (act4); and (5) the preservation of candung and water plants for all subak members (act5).

The results of the description of the action variable (act) in Table 6 show that Subak Lepud members were quite enthusiastic about cultivating candung and water plants on agricultural land, taking into account the average perception obtained by 3.15. Furthermore, it can be said that the construction of candung and water plants at the inlet position is believed to be carried out by Subak Lepud members because it obtained the highest average compared to other indicators, namely, 3.19. Meanwhile, the response to the construction of candung and water plants together with all subak members was the least, with an average of 3.13.

*Community potential*

The potential variable (pot) is interpreted as the view of Subak Lepud members regarding the opportunities that can be generated from the

cultivation of candung and water plants on agricultural land. In this study, the potential variable (pot) is measured by five indicators, namely: (1) increasing the value of local wisdom of subak (pot1); (2) producing sustainable healthy food products (pot2); (3) creating educational tourist attractions (pot3); (4) adding economic value to all subak members (pot4); and (5) preserving biodiversity in the land (pot5).

The description of the potential variables (pots) of Subak Lepud members in Table 7 shows that Subak Lepud members quite believed the cultivation of candung and water plants on agricultural land could provide promising opportunities in the future. This result is in accordance with the consideration of the average perception for the potential variable (pot) of 3.35. Furthermore, it can be said that the cultivation of candung and water plants is believed to have the potential to increase the value of subak’s local wisdom, because it obtained the highest average (3.43), followed by the potential to create educational tourist attractions (3.35), and produce sustainable healthy food products (3.35). The lowest response from Subak Lepud members was on the indicator of biodiversity preservation on land (3.32). The results of this analysis can provide clues that Subak

**Table 7.** Description of respondents on action variable (Act)

Description		Response (%)					Average (mean)
		1	2	3	4	5	
1	The construction of Candung and water plants at the inlet water (act1)	6.6	4.9	53.3	33.0	2.2	3.19
2	The construction of Candung and water plants together with all subak members (act2)	7.1	5.5	54.9	32.4	-	3.13
3	The selection of Candung and water plants that effectively absorb pollutants (act3)	6.6	4.4	57.7	31.3	-	3.14
4	The cultivation of Candung and water plants with economic value (act4)	6.6	4.2	57.9	31.3	-	3.14
5	The preservation of Candung and water plants for all subak members (act5)	6.6	4.4	57.6	31.4		3.14
Action variable (Act)							3.15

**Table 8.** Description of respondents on potential variable (pot)

Description		Response (%)					Average (mean)
		1	2	3	4	5	
1	Increasing the value of local wisdom of subak (pot1)	3.3	-	49.5	45.1	2.2	3.43
2	Producing sustainable healthy food products (pot2)	3.3	2.2	51.1	43.4	-	3.35
3	Creating educational tourist attractions (pot3)	3.3	-	55.5	41.2	-	3.35
4	Adding economic value to all subak members (pot4)	3.3	-	57.7	39.0	-	3.32
5	Preserving biodiversity in the land (pot5)	3.3		57.8	38.9		3.32
Educational tourist attraction potential							3.35

Lepud members tended to believe that the results of the cultivation of candung and water plants have the opportunity to increase the value of local wisdom, create educational tourist attractions, and produce sustainable healthy food products.

*Inferential analysis*

The inferential analysis used in this research is path analysis. Path analysis is a development of regression analysis that examines the causal relationships that occur in the variables studied, either directly (direct effect) or indirectly (indirect effect). The use of the AMOS program in this study is to help obtain a path diagram model simultaneously. Meanwhile, the use of regression analysis is to obtain a path diagram model that needs to be done in stages.

On the basis of the results of data analysis using path analysis with the decomposition model, namely the causal influence between variables, the factors that can determine the potential of cultivation of candung and water plants in Subak Lepud can be identified. The variables studied include knowledge (know) and experience (exp) as exogenous variables. Meanwhile, intention (intent) and action (act) are identified as intervening (mediation) variables and potential (pot) variables as endogenous variables in the path diagram model.

The path diagram model that is formed needs to be tested for model validation using the total determination coefficient (Dillon et al., 1984) with the following formula:

$$R_m^2 = R_{pe1}^2 \cdot R_{pe2}^2 \cdot R_{pe3}^2 \tag{1}$$

$$R_m^2 = 0.429 \cdot 0.494 \cdot 0.607 = 0.1286$$

where: model validation –  $1 - R_m^2$ ;  
 model validation – 0.9334 or 93.34%.

The results of the model validation mean that the diversity of the data can be explained by the path diagram model of 93.34%, while the remaining 6.66% is explained by other variables (which are not in the model) and errors. Thus, the results of the path analysis can be further explained by decomposing it into standardized regression coefficients. The decomposition of the results of the standardized path analysis (Table 8) shows that the five direct effect pathways have a significant effect ( $p \text{ value} < 0.05$ ). In the indirect effect test using Sobel’s test, three significant paths were obtained ( $p \text{ value} < 0.05$ ).

In further explanation, it can be said that *knowledge* has a positive and significant effect on *intention* with a path coefficient (standardized) of 0.308. The results of this analysis indicate that the knowledge of the cultivation of candung and water plants obtained will increase the interest of Subak Lepud members in using candung and water plants on cultivated agricultural land. Likewise, the effect of *experience* on *intention* has a positive and significant influence with a path coefficient (standardized) of 0.393. This result means that the more experienced Subak Lepud members are in the cultivation of candung and water plants, the more interest they have in using candung and water plants on cultivated agricultural land.

The information from Table 9 shows that *intention* has a positive and significant effect on *action* with a path coefficient (standardized) of 0.703. These results provide a direction to increase the interest of Subak Lepud members in cultivating candung and water plants, which will escalate the application of candung and water plants on their agricultural land. In other effects, *intention* has a positive and significant influence both directly and indirectly on *potential*, with a

**Table 9.** Decomposition of path analysis results (standardized)

Effect	Causal Effect		
	Direct effect	Indirect effect	Total effect
Intention ← Knowledge	0.308 <sup>s</sup>	-	0.308
Intention ← Experience	0.393 <sup>s</sup>	-	0.393
Action ← Knowledge	-	0.217 <sup>s</sup>	0.217
Action ← Experience	-	0.276 <sup>s</sup>	0.276
Action ← Intention	0.703 <sup>s</sup>	-	0.703
Potential ← Knowledge	-	0.230 <sup>s</sup>	0.230
Potential ← Experience	-	0.293 <sup>s</sup>	0.293
Potential ← Intention	0.526 <sup>s</sup>	0.221 <sup>s</sup>	0.747
Potential ← Action	0.313 <sup>s</sup>	-	0.313

**Note:** S – significant, NS – not significant.

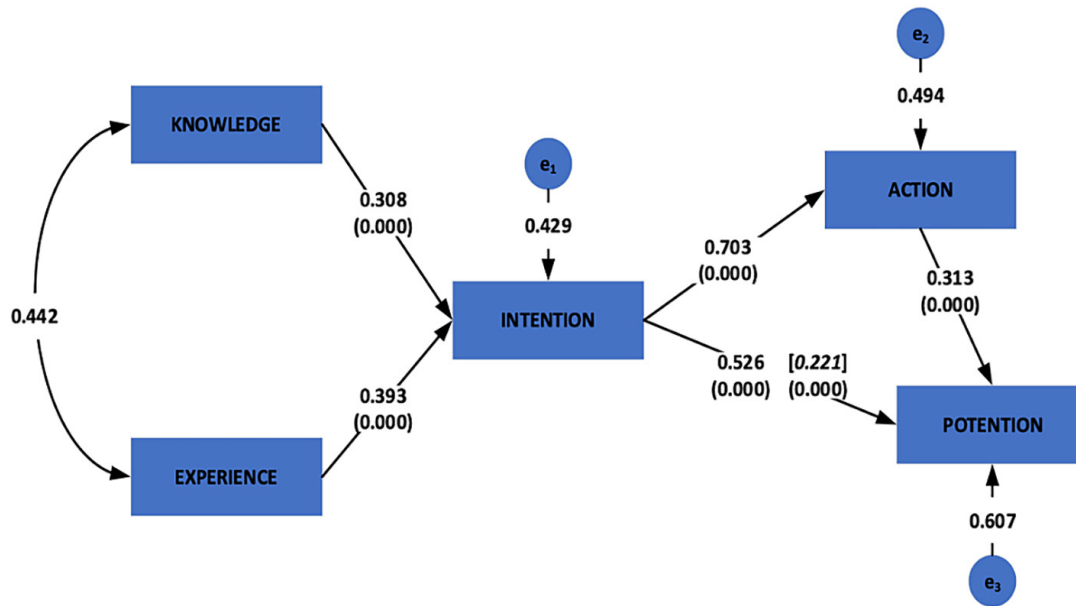


Figure 7. Analysis results path diagram model (Standardized)

direct effect path coefficient (standardized) of 0.526 and an indirect effect path coefficient (standardized) of 0.221. The results of the analysis indicate that the increased interest of Subak Lepud members in cultivating candung and water plants can provide a more promising potential for cultivated agricultural land if it is based on real and serious actions. Meanwhile, the *action* to cultivate candung and water plants was found to have a positive and significant effect on *potential* with a path coefficient (standardized) of 0.313. In order to clarify the results of the analysis obtained, a path diagram model can be presented in Figure 7.

On the basis of the information in Table 8 and Figure 1, it can be found that *intention* derived from *experience* will have a greater impact on the *actions* that Subak Lepud members will take to cultivate candung and water plants if sourced from *knowledge*. This finding certainly further confirms the *potential* obtained by Subak Lepud members from the results of cultivating candung and water plants on cultivated agricultural land.

## CONCLUSIONS

Candung is one of the local wisdom in Bali Island, acting as a constructed wetland that aims to maintain the irrigation water before entering the paddy fields. It is also a preservation of the paddy field ecosystem in order to prevent pollution and ensure the food material (rice) is safe. The effect of candung in maintaining the water

quality showed a good result in removing the water quality parameters, such as TSS, BOD, COD, and nutrients with certain water plants (*Nelumbo nucifera*, *Nymphaea tetragona*, *Pistia stratiotes*). The knowledge, behaviour, and action of the local subak community were still limited, whereas they had positive perceptions and responses about candung's potential as an agrotourism attraction in the village.

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Decision: **accept**

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April 14, 2023

JEENG-04047-2023-02

Treatment Ability and Community Responses of Candung as an Appropriate Technology to Maintain Irrigation Water Quality

Dear Dr. I Ketut Sumantra,

I am pleased to inform you that your manuscript, entitled: Treatment Ability and Community Responses of Candung as an Appropriate Technology to Maintain Irrigation Water Quality, has been accepted for publication in our journal.

Thank you for submitting your work to us.

Kindest regards,

Prof. Gabriel Borowski

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# Treatment Ability and Community Responses of Candung as an Appropriate Technology to Maintain Irrigation Water Quality

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## ABSTRACT

With the burgeoning population, the community activities, such as laundering, washing, or even bathing, have expanded along the irrigation canal. Consequently, some chemicals from those activities are released and pollute the water body. Besides, the discharge of wastewater into the irrigation system is also an issue of public health concern, because it creates an environment conducive to the reproduction of any pathogenic agent. Using candung as constructed wetlands (CW)-like to treat the irrigation water in rice paddies would be an interesting tool for removing pollutants from the irrigation water. Candung, as a locally used CW in Bali Island, has been applied in the rice field long time ago. The present study aimed to examine candung as a local attached CW or treating irrigation water and analyse the community awareness regarding the candung application. The result showed a positive effect of candung in maintaining the water quality parameters, such as TSS, BOD, COD, and nutrients with certain aquatic plants (*Nelumbo nucifera*, *Nymphaea tetragona*, and *Pistia stratiotes*). The knowledge, behaviour, and action of the local subak community were still limited, whereas they had positive perceptions and responses about candungthe potential of candung as an agrotourism attraction in the village as well

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