

## Does the Value of Water-Related Ecosystem Services Capture Water Scarcity? Application to Rice Farming in the Mekong Delta of Vietnam?

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This study utilized the contingent valuation method to estimate the value of water-related ecosystem services (ES) in Vietnam, focusing on provisioning and regulating services for addressing water scarcity (WS) in rice farming. By incorporating gender and climate change perceptions, it expanded the existing literature on valuing river ecosystem services. The findings showed a significant number of households experiencing severe water scarcity in the past five years, with over 70% facing occasional or regular WS in the last 12 months. Rice farmers were willing to adopt coping measures and preventive practices to preserve water-related ES, recognizing their importance for sustaining rice cultivation. Farmers demonstrated willingness to contribute financially to restore and maintain water-related ES in rivers and canals. The median willingness to pay for restoration was VND188,300/ha, with estimated values of US\$2,898,133 for a 10% affected area and US\$23,185,068 for an 80% affected area over five years. Perception of WS severity and associated risk positively influenced households' decisions to contribute financially. These findings have policy implications and provide insights for effective coping strategies against WS, enhancing water-resilient agriculture in the Lower Mekong Basin.

**Keywords:** Ecosystem services; water scarcity; rice production; WTP; Mekong delta of Vietnam; Lower Mekong.

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## 1. Introduction

The Mekong River, which flows into Vietnam through two tributaries, the Tien and Hau Rivers, and disperses into the delta through an intricate network of inter-connected canals, has been widely recognized as a vital water source for rice cultivation in the Lower Mekong Basin (LMB), particularly within Vietnam's Mekong Delta region (VMD). Over the past few years, water scarcity (WS) has emerged as a significant challenge that adversely impacts rice cultivation and the economic well-being of rural farmers in the basin (Lavane *et al.* 2023). In this study, water scarcity (WS) is defined as a water shortage affecting both the supply and quality of water for rice production, which is broader than the concept of "agricultural economic water scarcity", with a lack of irrigation due to limited institutional, economic, and hydrological constraints (Rosa *et al.* 2020). In 2021–2022, WS had a detrimental effect on 210,000 hectares of agricultural land, including rice farming areas in the VMD (Liem 2021). Although VMD is a principal rice bowl that accounts for nearly half of the national rice production area (Dung *et al.* 2022), rice cultivation has been reported to suffer dramatically from WS (Minh *et al.* 2022). WS has caused a 50% reduction in rice productivity in the VMD (Ha 2020). As a result, one of the critical demands in VMD is to maintain sufficient water quantity and acceptable water quality for rice production to ensure national food security and enhance farmers' welfare.

In recent years, reduced water supply has become common during the dry season, accompanied by negligible rainfall and decreased water flow downstream. The reduction in water quality is evident due to soil degradation and acidification caused by hydroelectric dam projects and the excessive exploitation of sand and groundwater upstream. This water scarcity (WS) has further implications in the context of climate change, including projected seasonal uncertainty, longer hot seasons, and decreased precipitation during the dry season (Johnston *et al.* 2020; Lange and Jensen 2013; Thilakarathne and Sridhar 2017; Osman *et al.* 2016). These WS facts have led to additional threats to rice cultivation, affecting both crop yield and water footprint (Arunrat *et al.* 2022; Jia *et al.* 2022). Rice, being a water-intensive crop, is anticipated to experience declines in yield under certain climate change scenarios during the mid and far-future periods (Arunrat *et al.* 2022). While WS is partially attributed to natural causes, human practices have significantly jeopardized water resources in the VMD. In practice, farmers often resort to their own means to cope with water shortages, lacking long-term strategic solutions. The rural poor, in particular, are highly vulnerable due to their financial and locational constraints. Therefore, participatory and bottom-up approaches to water management hold promise for policies addressing water security. In this effort, in addition

to human-based measures, nature-based solutions should be encouraged to enhance ecosystem services and mitigate WS (Seddon *et al.* 2020), particularly in developing nations.

The river flows in the upstream section of An Giang Province, specifically in the study areas like Tan Chau and Chau Doc (at the confluence of the Chau Doc and Hau River), play a significant role in providing and regulating water-related ecosystem services (ES) for rice production in the area and the downstream section of Can Tho City. Upstream flow, in particular, contributes to supplying irrigation water, maintaining water quality, purifying water, stabilizing water sources, and regulating natural hazards. Effective management of upstream water flow ensures the sustainability of provisioning and regulating ES for water resources in the area and downstream, thus providing critical support for rice cultivation downstream. However, in practice, recurring erosion and landslides along riverbanks and upstream canals, droughts, water depletion, and water pollution in rivers and canals have inevitably had adverse effects on the provision and regulation functions of water-related ES for agricultural production (AGO 2018; TTXVN 2019; Truc and Hung 2019; VJST 2020). Extreme weather events and climate change (Navarro-Ortega *et al.* 2015) can further exacerbate the risk of deterioration of water ES. Therefore, managing water resources equitably and sustainably for rice farming to cope with water scarcity (WS) in the context of climate change and increased uncertainty becomes one of the region's highest priorities. Considering the region's heavy reliance on water resources for local communities' livelihoods and food security, valuing water-related ES can serve as the foundation for policymakers and water users to develop a comprehensive water resource management plan.

The contingent valuation method (CVM), a common valuation technique, has been widely used in previous studies to assess the willingness-to-pay (WTP) for water-related ecosystem services (ES) (Aman *et al.* 2020; Barton 2012; Exposito 2019; Loomis *et al.* 2000; Meynell *et al.* 2021; Reynaud *et al.* 2015; Yang and Liu 2020) or to evaluate households' WTP for access to irrigation water (Mekonnen *et al.* 2020). Examining the value of either single ES (Barton 2012; Young *et al.* 2022) or bundled ES (Loomis *et al.* 2000; Wang *et al.* 2021; Yang and Liu 2020) of water resources, these previous studies show that households are willing to contribute financially to the maintenance of the water-related ecosystem value associated with rivers and lakes.

The key objective of this study is to estimate the value of water-related ecosystem services (ES) by employing the contingent valuation method (CVM), with a focus on provisioning and regulating services that address water scarcity (WS) and ensure water supply and quality for rice farming in Vietnam, a major global rice producer. This study makes three contributions to the literature. First, it

expands upon the existing body of literature on the valuation of river ecosystem services associated with provisioning and regulating benefits aimed at mitigating the impacts of WS in rice cultivation, particularly in the context of a developing country in Southeast Asia. Second, to the best of our knowledge, only a limited number of studies have incorporated the gender involvement and perceptions of coping strategies through the lens of managing blue and green water resources and climate change perceptions in the valuation of water-related ES to tackle WS in Southeast Asia. This study investigates the impact of the gender perspective and farmers' perceptions of coping strategies, within the context of managing blue (surface water) and green (soil water storage) water resources, as well as climate change perceptions on their valuation of water-related ES to overcome WS and promote sustainable water use for rice farming in the VMD. Third, the findings of this study provide valuable insights for water governance policies that incorporate nature-based measures to address risks associated with WS and enhance the provision of water-related ES in the VMD. Assessing water-related ES from the rivers in the capture of water demand for rice farming in Vietnam is crucial for raising community awareness about resource scarcity, supporting sustainable management strategies of ES, and improving rice production adaptation tools in the context of increased WS, climate change, and competing water users. As part of this study's effort, a comprehensive valuation of water-related ecological values is expected to update the value of water resources and serve as a foundation for developing decision-supporting tools in water network operation and water governance in agricultural production.

The remainder of this paper is structured as follows: Section 2 provides a review of the background literature and proposes the conceptual framework. Section 3 outlines the methodology, while Sec. 4 presents the results. Finally, Sec. 5 offers a discussion of the findings, and Sec. 6 draws conclusions.

## 2. Background and Conceptual Framework

Rivers and waterways benefit human life by providing water resources for various purposes, including agriculture, fish habitats, and recreation. The full range of ecosystem services (ES) provided by river and wetland ecosystems may include provisioning, regulating, supporting, and cultural services (Millennium Ecosystem Assessment 2005). Provisioning and regulating water-related services are particularly important and typical functions provided by rivers and canals. Table 1 illustrates the provisioning and regulating services associated with water from rivers and canals that support agricultural production.

**Table 1.** Water-Related Ecosystem Services from Rivers and Canals in Support of Agricultural Production

| Provisioning                                                                                                                                      | Regulating                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|---------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Water supply</b> <ul style="list-style-type: none"><li>• Irrigation water</li><li>• Rural water supply</li><li>• Water for livestock</li></ul> | <b>Water quality</b> <ul style="list-style-type: none"><li>• Maintaining water quality</li><li>• Waste water treatment — Water purification</li><li>• Water-borne disease regulation</li><li>• Pest and invasive species regulation</li></ul> <b>Flows</b> <ul style="list-style-type: none"><li>• Surface water sources</li><li>• Ground water recharge</li><li>• Ground water discharge</li></ul> <b>Natural hazard regulation</b> <ul style="list-style-type: none"><li>• Water storage for WS risk reduction</li><li>• Flash flood risks reduction</li><li>• Dispersion of flood waters</li></ul> |

(Source: Adapted from (Meynell *et al.* 2021)).

Among the water-related ecosystem services (ES) associated with rivers and canals, provisioning and regulating services are fundamental components. Provisioning services directly support human life. The security of water supply for irrigation is the core ES of Southeast Asian rivers (Meynell *et al.* 2021). Regulating services regulate and preserve ecosystem processes to support their functioning and productivity. Maintaining surface water flows, water quality, and water storage for water supply risk reduction are essential functions of Southeast Asian rivers (Meynell *et al.* 2021). Water-related ES, in the case of provisioning and regulating services of rivers and canals, are typical in terms of use values but may also include non-use values, such as the existing value associated with the availability of ES functions for future generations. Therefore, to comprehensively assess the value of water in agricultural production in the context of increasing water scarcity, droughts, extreme weather events, and climate change, stated preference methods have been proposed. The use of an ES approach to evaluate the value of water-related services from rivers can provide useful insights for policymakers and practitioners in developing potential strategies for more sustainable water use to cope with water scarcity.

Various studies in different water-based regions have examined the value of a single or bundle of water-related ES via exploring the value of willingness to pay (WTP). For example, Loomis *et al.* (2000) evaluated different types of river ES (including wastewater dilution, water purification, erosion control, habitat for fish and wildlife, and recreation) and found an average WTP of US\$21 per month for

the additional ES. The WTP for the preservation of freshwater supplies was approximately US\$19.7 annually (Wang *et al.* 2021). Yang and Liu (2020) found a total WTP of 67.1 RMB100Million for provisioning services, regulating services, and water purification. Similarly, Pérez-Blanco and Sapino (2022) found that the median annual value of ES (provisioning, regulating, cultural, and habitat) in the Reno River LRIB is € 126/ha. The WTP for ES of provisioning water from the Buffalo National River was estimated at around \$36/ha per year (Young *et al.* 2022). The WTP for improving the water quality and quantity in the Wei River basin was approximated to be RMB103.78 per year (Khan *et al.* 2019a). The estimated annual WTP for the restoration of river water quality in the Heihe River Basin was RMB124.81 (Khan *et al.* 2019b). Over 77.9% of the participants were found to be willing to pay for maintaining ES in regulating water in a watershed in Brazil (Reis *et al.* 2022). In relation to improving irrigation water, the mean WTP for improved irrigation water was roughly calculated to be US\$16 per 0.25 ha per year (Aman *et al.* 2020). Households were found to be willing to pay € 29,382.7 per year for sustainable irrigation water use by improving water storage, allocation, and distribution channels (Getnet *et al.* 2022). Mekonnen *et al.* (2020) found a WTP of US\$43.56 per ha for the management and maintenance of irrigation water schemes. Kidane *et al.* (2019) found that farmers were willing to pay approximately 5% of average farm income for improving irrigation water. Besides the stated WTP, in another strand, advanced agricultural system was introduced, such as the adoption of co-culture of rice-fish system, offers a potential solution to reduce pesticides and herbicides, enhance positive outcomes for ecosystem services via increasing water storage (Arunrat and Sereenonchai 2022) and promoting groundwater conservation (Arunrat and Sereenonchai 2022; Liu *et al.* 2020). These evidence-based studies suggest the growing awareness of local people for the importance of the water-related ES in supporting agriculture and human well-being.

Based on the literature review, insights from discussions with experts and stakeholders, and actual local context, the conceptual framework of this study is proposed as follows.

The valuation of water-related ES has been influenced by a number of factors, mainly including bid levels, perceptions, and socioeconomic characteristics of the participants.

In terms of socioeconomic characteristics, a number of rice farmers' features have been explored in the valuation of water-related ES. For instance, age has been found to have negative impacts on WTP in some cases (Aman *et al.* 2020; Khan *et al.* 2019b; Kidane *et al.* 2019), but negligible impacts in other context (Khan and Zhao 2019). Most studies have found no significant evidence of gender on

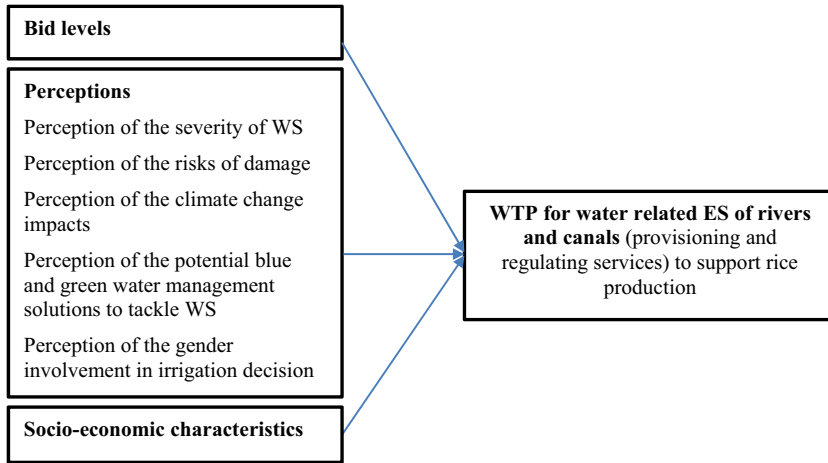


**Figure 1.** Conceptual Framework of Valuation of Water Related ES of Rivers and Canals (Provisioning and Regulating Services) to Support Rice Production

WTP (Aman *et al.* 2020; Kidane *et al.* 2019). The effect of education varies from neutral (Kidane *et al.* 2019) to positive (Aman *et al.* 2020; Ejeta *et al.* 2019; Khan and Zhao 2019; Khan *et al.* 2019b; Thapa *et al.* 2022) or negative (Ikikat Tumer 2020). Income has been found to positively influence WTP for improved irrigation water use (Ejeta *et al.* 2019; Khan and Zhao 2019; Khan *et al.* 2019b; Kidane *et al.* 2019; Thapa *et al.* 2022; Wang *et al.* 2021), whereas some studies have found no evidence of income effect (Aman *et al.* 2020; Ikikat Tumer 2020). The effect of household size was identified to be heterogenous from neutral (Khan and Zhao 2019; Kidane *et al.* 2019), to positive (Ejeta *et al.* 2019; Thapa *et al.* 2022) or negative (Khan *et al.* 2019b).

In terms of bid level, previous studies found that WTP tends to decrease with increased bid levels (Ejeta *et al.* 2019; Ikikat Tumer 2020; Khan and Zhao 2019; Kidane *et al.* 2019; Loomis *et al.* 2000). In term of perception, the perception of the scarcity of irrigation water or risk perception was found to positively influence the WTP (Kidane *et al.* 2019). People with higher perceived importance of ES tend to state higher WTP for the different ES functions in the US Rio Grande Basin (Wang *et al.* 2021). Also, perceived severity or negative experience/exposure to certain events may determine the WTP for measures to tackle a given issue (Sreenonchai *et al.* 2020). In more details, the perceived awareness of potential blue and green water management approaches to tackle WS is incorporated into this conceptual framework. It is predicted that by 2050, 59% of the world population will have to confront with blue WS, while 36% will experience green and blue water shortages. This raises the significance of the inclusion of management

of green and blue water resources in the context of the assessment of water availability under climate change and increased population, as characterized in the HadCM2 A2 climate scenario (Rockström *et al.* 2009). As mentioned earlier, this study contributes to the previous literature and addresses the research gap by investigating the effect of perception of coping strategies related to improving blue and green water resources on rice farmers' valuation of water-related ES. This approach aims to understand how vulnerable populations think of potential solutions to cope with WS, which may be beneficial in uncovering various possibilities for dealing with WS in the local area. Additionally, this study assesses the valuation of water-related ES of rice farmers resided in both the upstream and middle/lower part/downstream of the VMD to improve the ES upstream to tackle WS for agricultural production in the basin, which has rarely been examined in past research. By incorporating the participation of rice farmers in both the upstream and downstream sections of a given river basin, the valuation of water-related ecosystem services can capture the diverse local production conditions, farming/irrigation practices, varying levels of water scarcity experience/exposure, interconnectedness of the river ecosystem, and interdependencies of water-related ecosystem services throughout the entire river. This approach contributes to promoting a stakeholder engagement perspective and utilizing the advantages of a holistic approach in valuing the water ecosystem services of the river. Such an inclusive approach can increase the representativeness of the participants in evaluating the water-related ecosystem services of a river basin and contribute to more comprehensive insights into the assessment of measures for sustainable management and conservation of water-related ecosystem services of the river to cope with water scarcity, particularly under growing threats of climate change and changing production conditions.

### 3. Methodology

#### 3.1. Study areas

Two major rice-producing areas in the VMD, namely An Giang and Can Tho (Figure 2), have been selected as targeted study areas due to the increased risk of WS, which poses threats to rice cultivation in recent years. An Giang, located in the upper reaches of the VMD, had a population of over 2.4 million people as of 2019. The province covers a total area of 3,536 km<sup>2</sup>, with 70% of it being agricultural land, and rice is the most dominant and crucial crop (Thu Minh *et al.* 2020). An Giang had a total cultivated area of paddy fields exceeding 680,000 ha in 2019, with an average rice yield of 6.3 tons per hectare. It stands as one of the country's largest rice-producing provinces, with an annual rice output of nearly

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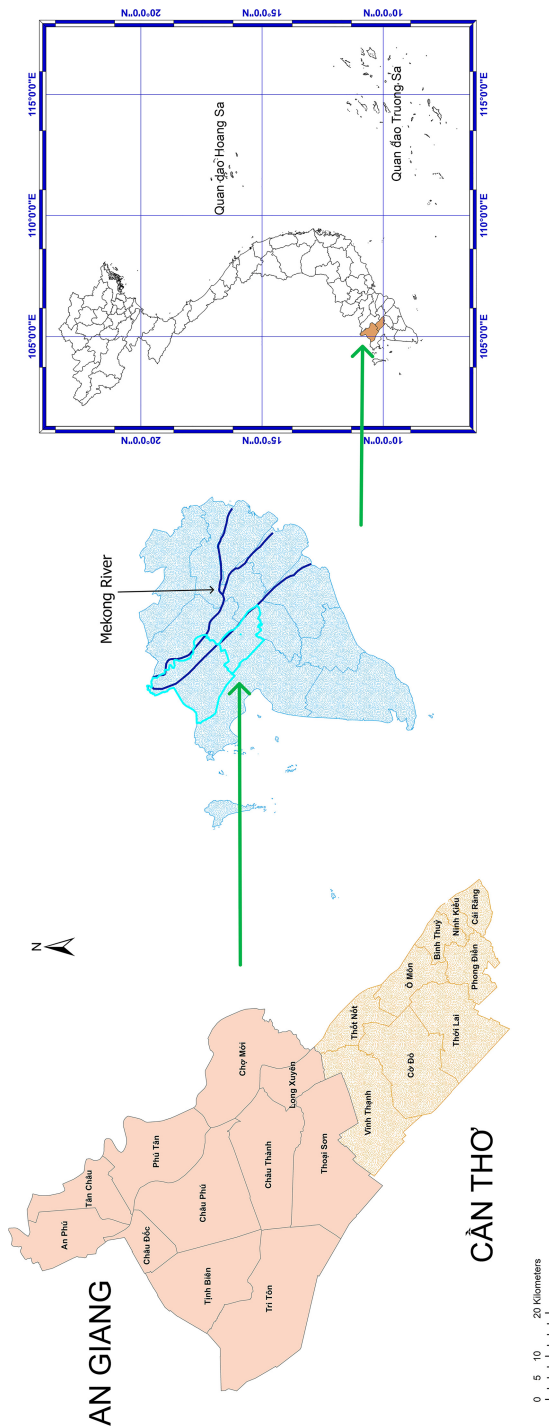


Figure 2. Map of Study Area of An Giang and Can Tho City in the Mekong Delta of Vietnam

4 million tons (Sang 2020). Despite having abundant water resources due to its location upstream of the Tien and Hau Rivers, An Giang is one of the provinces most vulnerable to weather and climate risks, particularly severe WS and drought in agricultural production, including rice cultivation. Statistical estimates indicate that An Giang experienced 33 moderate, 14 severe, and 13 extremely severe droughts from 1984 to 2015 (Lee and Dang 2019). In 2020, the An Giang Hydro-Meteorological Station reported that the flow of water from the upstream Mekong River to the region during the first months of the dry season was 20% to 50% lower than the usual average. This resulted in dangerously low water levels in many rivers and canals, leading to earlier, more intense, and severe WS in the area. Water scarcity is common in certain districts, particularly Thoai Son, Tinh Bien, and Tri Ton, especially during dry years, due to an increase in competing water users. As An Giang is located upstream, the provision and regulation of water resources are essential for meeting the water demands of agricultural production in the region and downstream areas.

Can Tho, a city located in the downstream section of the VMD, heavily relies on water sources from upstream for rice farming. The city has 87,988 ha of rice cultivation and an annual rice-growing area that exceeds 237,000 ha (MARD 2019). However, there is growing evidence indicating that the water levels in Can Tho's rivers and canals, which are the main water supply for rice fields and agricultural production areas, have been relatively low in recent years (Hoai 2022). Many canals are dry or deteriorating, posing a threat to water supply and rice production (DWRM 2022). Particularly, the districts located far from the Hau River are unable to provide sufficient water to the fields. As a result, local farmers in these districts must dredge canals to redirect the flow and pump water, leading to high production costs (Hoai 2022). In addition to the reduced water supply, the changed water quality has also affected downstream agricultural production and degraded downstream water quality. The quality of water downstream has been heavily influenced by the amount of pollutants released into the upstream watershed (Yoon *et al.* 2015). Additionally, the capacity of the downstream river to dilute pollutants has been considerably diminished by excessive/uncontrolled water extraction activities upstream, resulting in a significant degradation of water quality downstream (Yoon *et al.* 2015). Microbial contamination in water bodies in An Giang and some other areas in the Mekong Delta is a major concern that negatively affects water quality and poses a threat to human health in the area and downstream, for instance in Can Tho (Ly and Giao 2018). While previous literature has predominantly concentrated on water allocation between upstream and downstream areas, minimal consideration has been given to downstream water in cases of diminishing stream flow (Bennett 2000; Yoon *et al.* 2015). As a result,

water management in An Giang plays a pivotal role in shaping the water supply and water quality of neighboring/adjacent provinces, such as Can Tho (Hong and Giao 2022), especially for rice production, a crucial crop in the basin.

In June and July 2019, The Mekong River Commission (MRC) reported that the river water level was below the long-term average minimum (MRC 2019). Extreme events such as WS and droughts during the dry season, as well as the effects of El Niño and La Niña, may further exacerbate the risk of WS in the basin (Hong 2020). These facts necessitate immediate measures and actions to support water recirculation and conserve water resources for agriculture and rice production in VMD.

### **3.2. Contingent valuation method**

This study applies a contingent valuation method (CVM) to evaluate local rice farmers' preferences for the ES of rivers and canals, specifically those pertaining to water provision and regulation services for rice production. CVM is particularly helpful in assessing both the use and non-use values of ES associated with rivers and canals, such as provisioning and regulating services of water for irrigation and agricultural purposes (Aman *et al.* 2020; Exposito 2019). Participants were introduced to a scenario and asked to indicate their WTP for the improvement of such ES. Due to the limited options available for payment vehicles, the majority of households in the study area rely solely on the payment of water bills as a method to access water. Therefore, the water bill is considered a suitable payment vehicle in this context.

#### **3.2.1. Development of survey questionnaire and valuation scenarios**

A variety of datasets had been employed to evaluate the ecosystem services (ES) associated with rivers and canals. The CV questionnaire was developed in two phases. The first phase involved developing survey instruments and materials based on the information collected from secondary data, stakeholder consultations, key informant interviews, and focus group discussions in the middle of 2021. The second phase involves a pilot survey. Secondary data were collected annually from the Vietnam General Statistic Office, governmental agencies, and reports of local authorities to characterize the relevant characteristics of the study areas and assist in the design and sampling process.

In the first phase, the study depicted important issues related to water use and water scarcity in rice production in the study areas, informed by a review of literature and secondary data. This information was utilized to shape the study design and scenario development. To develop the questionnaire, twelve one-on-one semi-structured interviews were conducted with local policymakers, local

authorities at the provincial and commune levels, and stakeholders. The draft of the questionnaire underwent two focus group discussion (FGD) sessions, each involving eight households, and two FGD sessions with local stakeholders, with seven participants in each session. The FGDs involved local authorities at the commune and provincial levels, representatives of local farmers, village leaders, local extensionist/irrigation experts, representatives of farmer associations, and women's associations. These FGDs facilitated the exchange of ideas, feedback, and suggestions regarding the current situation, challenges, and threats of water use in rice production in the study areas, as well as future plans related to water use and irrigation in rice production under increased water scarcity. The information gathered from these FGDs was used to develop scenarios and prepare the survey questionnaire. In the subsequent step, ten cognitive interviews were conducted with households in each city, and three expert reviews were undertaken to gather feedback on the draft questionnaire.

The information gathered from the first stage of the questionnaire development enabled us to accomplish the following:

- (i) Identify and verify the pertinent information required for describing the valuation scenario.
- (ii) Evaluate the feasibility and viability of the proposed programs, policies, and payment vehicle.
- (iii) Receive feedback regarding the clarity of the terms, language, and content of the questions in the questionnaire.

We utilized all the feedback received to create an enhanced version of the questionnaire.

In the second phase of questionnaire development, a pilot survey was conducted at the beginning of 2022, involving 60 households. The pilot survey proved to be particularly helpful, as it not only allowed for a recheck of the questionnaire but also helped identify potential issues that may arise during the survey administration.

The final questionnaire consists of three parts. The first section includes questions regarding farmers' perceptions of water use in rice production and their risk perception. The second section examines farmers' preferences and valuations of the water ecosystem services (ES) provided by rivers and canals, aiming to address water scarcity (WS) and support rice production. Lastly, the final section collected socioeconomic profiles of the participants.

In the questionnaire, the valuation scenario was designed based on discussions with stakeholders. Participants were first presented with a number of key terms, the current situation of water scarcity in rice cultivation in the Vietnamese Mekong

Delta (VMD) in An Giang and Can Tho city, and the linkage of river flow from An Giang (upstream) to Can Tho (downstream). Next, participants were provided with an introduction to the study area, which is the upstream area of the Mekong River, specifically the intersection of Tan Chau and Chau Doc (the confluence of Chau Doc and Hau Rivers). This section of the river plays a crucial role in supplying and maintaining water sources for rice production in the delta. Before responding to the valuation questions, participants were given a clear explanation of the pivotal roles of ecosystem services (ES) associated with rivers and canals in providing and regulating water sources for rice cultivation. Specifically, the water flow of the river upstream of the Vietnamese Mekong River in An Giang provides key ecological services, including supplying irrigation water for rice cultivation, maintaining and stabilizing the flow, and ensuring water distribution to downstream sections such as Can Tho. It secures water sources for rice farming and livelihoods in An Giang and ensures steady water resources for rice cultivation and sustenance in the downstream area, such as Can Tho. Importantly, the ecosystem services of the river in the upstream in An Giang are crucial in naturally purifying water, mitigating the negative impacts of wastewater, facilitating wastewater dilution, preventing erosion, and regulating and maintaining water quality both in the province and downstream sections in Can Tho. In addition to securing surface water sources, the ecosystem services of water flow can aid in the recharge and discharge of groundwater to prevent water scarcity. Therefore, guaranteeing the quantity and quality of water flow in rivers and canals can support the mitigation of the risk of water scarcity and the regulation of natural hazards through the water storage function. The conservation of water-related ecosystem services in critical areas of the upstream section of the Vietnamese Mekong River in An Giang, such as the area that passes through Tan Chau and Chau Doc (Chau Doc and Hau River confluence), is crucial for securing water for rice cultivation in both An Giang and Can Tho. Moreover, conserving water-related ecological services of rivers and canals can provide a habitat for fish and wildlife and offer further opportunities for recreation and other economic benefits.

Notably, this section highlights the various challenges faced by rice farmers in managing ecosystem services (ES) in rivers and canals, particularly concerning the provision and maintenance of water resources for rice production in this area. These challenges encompass the instability of water flow, deterioration of water quality, alterations in flow patterns caused by erosion, allocation of water in the rivers and canals for rice farming, and the vulnerability of the area during prolonged dry periods. Consequently, participants were informed about the crucial role of effectively maintaining and restoring ES associated with rivers and canals to

address water scarcity (WS). It is emphasized that the neglect of rehabilitating and conserving such ES can further exacerbate the issue of WS in the delta.

Afterward, participants were introduced to the activities proposed to preserve and sustain the ecosystem services (ES) of rivers and canals, particularly regarding their roles in water provision and regulation functions for rice production. This section also highlights the mechanism of provision and the agencies responsible for implementing the program, as well as the statement of consequences and payment mechanisms. Participants were also informed that the results of the study will be shared with local authorities and relevant decision-makers, which makes the hypothetical payment real and creates an incentive-compatible response.

Through the interview, it was rather straightforward to perceive the benefits of the ES provided by rivers and canals in water provisioning and regulating functions for rice production, which were presented to households in An Giang. As farming households in Can Tho are located in the middle and downstream of the VMD, they could be aware of and stand to gain significant benefits if these ES are properly maintained and restored. Enhancing the water flow and water quality along the rivers could directly contribute to addressing risks associated with WS in the delta. To minimize hypothetical bias, a cheap talk script was used to remind households of their budget constraints. Following that, participants were asked to indicate their WTP for the preservation of ES associated with rivers and canals, specifically water provision and regulation functions for rice cultivation at the intersection through Tan Chau and Chau Doc via a Watershed Care Fund. The WTP question was: "Would you vote for these measures if they cost your household *<bid level>* per 1,000m<sup>2</sup>/ crop/ year for the next 5 years payable as surcharge on your water bill to maintain and restore the ES of rivers and canals relating to water provisioning and regulating services for rice farming at the intersection through Tan Chau and Chau Doc?" The five bid levels employed were VND5,000, 10,000, 20,000, 35,000, and 55,000. The answers indicate either "yes" or "no". Farmers' willingness to pay (WTP) can be determined through the water bill using bid levels or through the contribution of labor measured in working days per year. Surcharge via water bill will be collected at the end of each crop.

### 3.2.2. *The contingent valuation method*

The contingent valuation method (CVM/CV) is a direct survey approach used to elicit individual preferences for a particular change in the provision of (non-market) goods or services (Mitchell and Carson 1989; OECD 1995). CV has been widely used to estimate water-related ES (Aman et al. 2020; Barton 2012; Exposito 2019; Loomis et al. 2000; Meynell et al. 2021; Reynaud et al. 2015; Yang and Liu 2020).

As mentioned earlier, the ES of rivers and canals can provide various benefits, including water provisioning, such as irrigation water supply, regulating services through the maintenance of surface water flows and water quality, and conservation of water resources for WS risk reduction (Meynell *et al.* 2021). In this study, the CVM was applied to estimate the WTP for the maintenance and restoration of water ES of rivers and canals (provisioning and regulating services) linked to rice production at the intersection through Tan Chau and Chau Doc in An Giang Province to cope with WS and improve livelihoods for local communities.

The discrete choice contingent valuation question, among others, is the most commonly adopted because of its capacity for incentive compatibility (Carson *et al.* 2001). A random utility model is usually applied (Bateman *et al.* 2002; Haab and McConnell 2002) in which the utility function of respondent  $j$  is:

$$u_{ij} = u_i(y_i; z_i; \varepsilon_{ij}), \quad (1)$$

where  $i = 0$  is the status quo, and  $i = 1$  is the condition where the ecosystem services are provided. Utility is a function of income  $y$ , a vector of participants' characteristics  $z$ , and  $\varepsilon_{ij}$  represents the unobservable component. Participants are willing to pay or saying "yes" to the payment  $t_j$  if the utility after the payment exceeds the utility of the status quo, or

$$u_{ij} = u_1(y_j - t_j; z_j; \varepsilon_{1j}) > u_0(y_j; z_j; \varepsilon_{0j}). \quad (2)$$

Due to the unobservable component, one can only estimate the probability of a "yes" or "no" response:

$$\Pr(\text{yes}_j) = \Pr(u_1(y_j - t_j; z_j; \varepsilon_{1j}) > u_0(y_j; z_j; \varepsilon_{0j})). \quad (3)$$

Suppose that the utility function is linear:

$$v_{1j}(y_j) = \sum_{k=1}^m \alpha_k z_{jk} + \beta_1(y_j). \quad (4)$$

The probability statement becomes:

$$\Pr(\text{yes}_j) = \Pr\left(\sum_{k=1}^m \alpha_k z_{jk} - \beta t_j + \varepsilon_j > 0\right). \quad (5)$$

### 3.2.3. Welfare measure

Both parametric and non-parametric estimations were used to estimate the value of provisioning and regulating services (ES) associated with rivers and canals to support rice production.

### 3.2.3.1. Non-parametric estimation

Non-parametric estimation is considered complementary to parametric estimates owing to concerns of improper specifications of functional forms and distributions in parametric estimation approaches (Cooper 1994). In addition, the results of the parametric approach can be validated using non-parametric estimates (Salazar and Marques 2005). In this study, the WTP is estimated using a midpoint estimation. Five bid levels were used including VND5,000, 10,000, 20,000, 35,000, 55,000. Let  $N$  denote the number of households in the sample and  $t_j$  the bid level ( $j = 0-J$ , where  $J$  is the highest bid level). The probability of a household answering “yes” ( $P_j$ ) is equal to the share of the total number of households that have confirmed their WTP over the total number of households participating at a particular bid level.

Given  $t_j$  as the bid level, if respondent  $i$  confirmed “yes” to price  $t_j$ , indicating that his  $WTP_i \geq t_j$ . If the answer is “no”,  $WTP_i < t_j$ . Hence, WTP can be considered a random variable with a cumulative distribution function,  $F_w(t_j)$ . The probability that a respondent has a WTP of less than  $t_j$  is shown below, according to (Haab and McConnell 2002):

$$\begin{aligned} \Pr(WTP_i < t_j) &= F_w(t_j), \\ \rightarrow \Pr(WTP_i \geq t_j) &= 1 - F_w(t_j) = P_j. \end{aligned} \quad (6)$$

The expected value of a random variable distributed between 0 and “a” (a parameter) is as follows:

$$E(WTP) = \int_0^a WTP dF_w = \int_0^a [1 - F_w] dWTP. \quad (7)$$

Because  $t_j$  refers to five bid levels,  $t_1$ ,  $t_2$ ,  $t_3$ ,  $t_4$ , and  $t_5$  have already been specified. The proportion of respondents answering “yes” ( $P_1$ ,  $P_2$ ,  $P_3$ ,  $P_4$ , and  $P_5$ ) was calculated.

The WTP according to the midpoint estimation is then obtained as follows:

$$WTP = \sum_{j=0}^J [(t_j + t_{j+1})/2] * (P_j - P_{j+1}). \quad (8)$$

### 3.2.3.2. Parametric estimation

In this study, a parametric method was applied to estimate WTP using probit regression.

### 3.2.3.3. Probit model

The dependent variable is the probability that households say “yes” or “no” to a particular bid level  $t_j$ . Several independent variables were included in the analyses,

including the bid levels, perceptions, and socioeconomic profiles of the participants.

$$\Pr(\text{yes}_j) = \beta_0 + \beta_1 t_j + \beta_j X_i + \varepsilon_j. \quad (9)$$

The mean/median WTP is obtained as

$$WTP = - \left[ \frac{\beta_0 + \sum \beta_j \bar{X}_i}{\beta_1} \right], \quad (10)$$

where  $\beta_0$  is a constant term,  $\beta_1$  is the coefficient of bid variable ( $t$ ), and  $\beta_j$  is the coefficient of the other variables  $X_i$ .

Validity of the CVM results was investigated using a valuation function (Eq. (11)). The dependent variable is the probability of a “yes” response for the WTP for the rehabilitation of the ES (provisioning and regulating services) associated with rivers and canals in An Giang to support rice production. The explanatory variables are bid levels, socioeconomic characteristics, and the attitudinal/perception of participants towards WS and water-related ES.

The regression equation of the valuation function can be written as follows:

$$\Pr(\text{Yes}) = \beta_0 + \beta_1 \text{Bids} + \beta_2 \text{Edu} + \beta_3 \text{Hhsize} + \beta_4 \text{Income} + \beta_5 \text{Severe} + \beta_6 \text{Risk} \\ + \beta_7 \text{Climate} + \beta_8 \text{Gendinvol} + \beta_9 \text{LocaStore} + \beta_{10} \text{IrriTech} + \varepsilon. \quad (11)$$

### 3.2.3.4. IV-Probit model

There could be an issue of endogeneity in the Probit model due to potential correlation between the perception of green water resources management (IrriTech) and the error terms. Specifically, there may be a two-way causality between the perception of green water resources management (IrriTech) and the willingness to pay. Knowledge about irrigation sources for rice could influence individuals’ perception of green water resources management (IrriTech) and their overall value for water conservation. If individuals have greater knowledge, they may be more likely to agree to pay and also hold a higher appreciation for the management of green water resources (IrriTech), which introduces simultaneity bias. To address the concern of endogeneity, an IV-Probit model is used by expanding Equation (9) as follows:

$$\Pr(\text{yes}_j) = \beta_0 + \beta_1 t_j + \beta_j X_i + \varphi_j IV_j + \mu_j, \quad (12)$$

where  $\beta_0$ ,  $\beta_i$  are the vector parameters for control variables,  $\varphi_j$  refers to as the parameter for the instrumental variable (IV),  $\mu_i$  is a random disturbance term.

It is necessary to identify a relevant and valid instrument for instrumental variable (IV) analysis. The procedure to test and verify the instrumental variable

was conducted, and ultimately, only the variable related to farmers' perception of the management of "*One Must Do, Five Reductions*" met the requirements to serve as an IV in the IV-Probit model. The variable "*One Must Do, Five Reductions*" measures the extent to which farmers agree that implementing the irrigation management program will help mitigate water stress in rice production. This program is an integrated technology package aiming to promote the adoption of effective and recommended management practices in lowland rice farming. The package includes the use of certified seeds, known as the "*One Must Do*" as well as reductions in seed rate, fertilizer and pesticide usage, water consumption, and postharvest losses (Connor et al. 2021). A description of the variables used in the model is illustrated in further detail in Table 2. The expected signs of the coefficients are presented in the last column.

### 3.3. Data collection and analysis

Based on the results of the literature review, key informant interviews, focus group discussions, and pilot survey, the questionnaire collected from farming households was improved and finalized. We used stratified sampling in combination with a quota sampling approach based on the distribution of rice production areas at the study sites, access to water and irrigation for rice production, and water scarcity in farming households. The sample size was decided based on the central limit theorem (CLT) to collect a minimum of 30 observations for a given bid level. A sample size of 300 to 500 is recommended in a contingent valuation study with 5 bid levels (Sajise et al. 2021). Following (Gunatilake et al. 2007) and Sajise et al. (2021), the rule of thumb for the target sample size is  $30 * 5 = 150$  observations for a contingent valuation study with 1 treatment and 5 bid levels.

The survey was conducted at the beginning of 2022 through face-to-face interviews with a total of 401 households in An Giang and Can Tho. More than 70% of the sample was allocated to An Giang, while the remaining households were surveyed in Can Tho city. This distribution was based on the fact that An Giang province has a larger area dedicated to rice cultivation in the VMD. In An Giang city, we conducted a survey of 291 households, covering almost all districts. These districts were specifically targeted due to their high proportion of rice cultivation across various types of terrain and their access to irrigation. The surveyed districts included Tri Ton, Tinh Bien, Thoai Son, Chau Thanh, Chau Doc, An Phu, Phu Tan, Tan Chau, and Cho Moi. In Can Tho City, we surveyed 110 households in two significant rice production areas: Co Do and Phong Dien districts. These areas have different levels of access to irrigation through rivers and canals. Within each district of the surveyed provinces, communes were selected for sampling

**Table 2.** Description of Variables used in the Model

|    | Variable                                                                                                                                    | Description                                                                                                                                                                                                                     | Value                                                        | Expected Sign |
|----|---------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|---------------|
| 1  | Prob(Yes)                                                                                                                                   | Probability of a respondent is willing to pay for the restoration and maintenance of the water ES (provisioning and regulating services) associated with rivers and canals at the study area to support rice production         | 1 = Yes<br>0 = No                                            |               |
| 2  | Bids                                                                                                                                        | Bid levels (1,000 VND)                                                                                                                                                                                                          | 5, 10, 20, 35, 55                                            | —             |
|    | <i>Socio-economic characteristics</i>                                                                                                       |                                                                                                                                                                                                                                 |                                                              |               |
| 3  | Age                                                                                                                                         | Age of the respondent in years                                                                                                                                                                                                  | Numeric variables                                            | + / —         |
| 4  | Edu                                                                                                                                         | Education of the respondent                                                                                                                                                                                                     | 1 = secondary and upper,<br>0 = otherwise                    | + / —         |
| 5  | Hhsize                                                                                                                                      | Number of members of each household (persons)                                                                                                                                                                                   | Numeric variables                                            | + / —         |
| 6  | Income                                                                                                                                      | Household's income                                                                                                                                                                                                              | Numeric variables                                            | +             |
|    | <i>Perceptions (WS, risk, climate, gender involvement, solutions to tackle WS in relation to management of blue, green water resources)</i> |                                                                                                                                                                                                                                 |                                                              |               |
| 7  | Severe                                                                                                                                      | Perception of the severity of WS in household rice production                                                                                                                                                                   | 1 = Yes<br>0 = No                                            | +             |
| 8  | Risk                                                                                                                                        | Perception of the risk of households' damage in rice production due to WS                                                                                                                                                       | 10-point scale from 0 = no risk, to 10 = extremely high risk | +             |
| 9  | Climate                                                                                                                                     | Perception of the climate change impacts (i.e., belief that climate change will increase the risk of WS in rice production in the LMB (future prediction))                                                                      | 1 = strongly disagree to<br>5 = strongly agree               | +             |
| 10 | Gendinvol                                                                                                                                   | Perception of the gender involvement in irrigation decision (i.e., involvement of women and men (main, co-responsible) in the family in accessing and using water for rice irrigation)                                          | 1 = agree and strongly agree;<br>0 = otherwise               | +             |
| 11 | IrriTech                                                                                                                                    | Perception of the potential green water management solutions to tackle WS (i.e., belief that investment in proper irrigation techniques for instance Alternate Wetting and Drying (AWD) can help to resolve WS in rice farming) | 1 = strongly disagree to 5 = strongly agree                  | + / —         |

**Table 2.** (Continued)

|    | Variable    | Description                                                                                                                                                                  | Value                                       | Expected Sign |
|----|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|---------------|
| 12 | LocaStore   | Perception of the potential blue water management solutions to tackle WS (i.e., belief that investment in the local water storage will help to tackle WS in rice production) | 1 = strongly disagree to 5 = strongly agree | +/-           |
| 13 | 1Must5Reduc | Perception of the management of irrigation according to the program <i>1 Must Do 5 Reductions</i> will help to cope with WS in rice production                               | 1 = strongly disagree to 5 = strongly agree | IV            |

Note: IV: Instrumental Variable.

based on the distribution of rice production and irrigation conditions. Within the communes, households were recruited and spatially stratified according to their distance to rivers and canals, level of access to irrigation, and socioeconomic profile. The collected data were carefully checked and entered into SPSS 26.0 and STATA 15 for further analysis.

The socioeconomic characteristics of the participants are presented in Table 3. Although gender issues were taken into account at the beginning of the survey, the predominance of males in the sample reflects the labor-intensive nature of agricultural activities, where men traditionally assume the responsibility for rice

**Table 3.** Characteristics of the Sample ( $n = 401$ )

| Items                              | %                                      |
|------------------------------------|----------------------------------------|
| Gender (% Male)                    | 89.3                                   |
| Age (years)                        | 45.73 <sup>a</sup> (9.87) <sup>b</sup> |
| < 35                               | 15.8                                   |
| 36–50                              | 53.1                                   |
| > 50                               | 31.1                                   |
| Education                          |                                        |
| Lower than primary school          | 67.8                                   |
| Secondary school                   | 24.7                                   |
| High school and upper              | 7.5                                    |
| Household size (persons)           | 4.31 <sup>a</sup> (1.18) <sup>b</sup>  |
| Household income                   |                                        |
| Less than 6 million VND/month      | 53.1                                   |
| From 6 million VND/month and above | 46.9                                   |

Note: <sup>a</sup>mean <sup>b</sup>Std.

cultivation. The majority of the participants, over 50%, fell into the age range of 36 to 50, with the average age of the sample being approximately 45 years.

## 4. Results

### 4.1. Water scarcity and households' rice production

#### 4.1.1. Severity of water scarcity in households' rice production

The severity of WS in rice production in the study area is presented in Table 4. A considerable proportion of households, exceeding 50%, confirmed to have been severely affected by WS during cultivation within the past five years. Additionally, more than 70% of the households reported sometimes to regularly having experienced significant impacts of WS in the last 12 months. Households have adopted various coping measures to respond to increased WS. Over 40% of households reported an increase in the frequency of coping mechanisms such as pumping events, to combat WS within the last five years, highlighting the possibility of inconvenience and disruption to household production caused by WS.

#### 4.1.2. Household's perception of water scarcity in rice production

To understand thoroughly the influence of WS on households' rice production and livelihoods, their perceptions of the WS are presented in Table 5. Responses were rated on a five-point Likert scale. Households generally concur that WS is a significant concern in rice farming in their cultivating areas. Most households supported the idea that managing ES of upstream rivers and canals in An Giang would aid in regulating the flow to production areas in the entire VMD. This suggests that households have recognized the positive impacts of upstream conservation activities on the basin's rice production. More specifically, households highly value the provisioning and regulatory functions of water ES for rice cultivation.

In this study, households were asked to consider several coping measures to improve blue water (water harvesting/storage systems) and green water

**Table 4.** The Influence of WS on Households' Rice Production

| Items                                                                                                 | %    |
|-------------------------------------------------------------------------------------------------------|------|
| • Severely influenced by WS in the past 5 years (% Yes)                                               | 55.9 |
| • Frequency of suffering from WS in the last 12 months (% Sometime & Regularly suffering from WS)     | 72.1 |
| • Frequency of coping mechanisms (pumping water, etc.) in the last 5 years (% increased coping times) | 41.5 |

**Table 5.** Household’s Perception Towards WS in Rice Production

| Items                                                                                                                                                             | Mean | Std. |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|
| WS is a serious issue in rice production at the plots/area that your household are currently cultivating.                                                         | 3.71 | 0.91 |
| Management of ecosystem services (ES) of the upstream rivers and canals (in An Giang) will help regulate the flow to support households’ production in the basin. | 3.93 | 0.89 |
| Management of ES of rivers and canals upstream (in An Giang) will help to secure and increase water supply for households’ rice cultivation areas.                | 3.70 | 1.13 |
| Management of ES of rivers and canals upstream (in An Giang) will help to maintain water quality for households’ rice cultivation areas.                          | 4.10 | 0.89 |
| Investment in local water storage will help to tackle WS in rice production.                                                                                      | 3.82 | 1.19 |
| The use of proper irrigation techniques for instance Alternate Wetting and Drying (AWD) can help to resolve WS in rice production.                                | 4.26 | 0.80 |

(enhancement of soil moisture via improved irrigation techniques) to combat WS. Investment in water storage systems to alleviate WS at the local level is considered a potential option. Also, households strongly support the idea that the implementation of proper irrigation techniques, such as alternate wetting and drying (AWD), can contribute to overcoming WS in rice production. These attitudes and perceptions of households are used to describe additional factors that may influence farmers’ WTP to tackle WS.

**4.2. Determinants of the probability of agreeing to an offered bid**

Table 6 presents the empirical results for the determinants of the probability of agreeing to an offered bid. The Probit model and IV-Probit model were employed. In the Probit model, eight determinants, including bid levels (Bid), household income (Income), severity (Severe), risk, climate, Gendinvol, LocaStore, and IrriTech, were identified as explanatory factors affecting households’ willingness to pay (WTP) for the restoration and maintenance of water ES to support rice production (see Table 6).

The variable *1must5reduc* was selected as an IV with careful consideration of the relationship between the management of *1must5reduc*, the perception of management of green water resources (IrriTech) (treatment), and the willingness to pay (outcome). Linked to theoretical and practical perspectives, the ease of following “One Must Do, Five Reductions” (*1must5reduc*) were found to positively and significantly influence the adoption for proper irrigation technique such as AWD (Connor et al. 2021). Hence, farmer who shows a higher appreciation for the *1must5reduc* may also exhibit greater concern or higher awareness/knowledge for the perception of management of green water resources (IrriTech). Follow that

**Table 6.** Determinants of WTP

| Variables                                                                                                                                   | Probit Model |             |         | IV-Probit Model |             |         |
|---------------------------------------------------------------------------------------------------------------------------------------------|--------------|-------------|---------|-----------------|-------------|---------|
|                                                                                                                                             | B            | Robust S.E. | p-value | B               | Robust S.E. | p-value |
| Constant                                                                                                                                    | −4.36***     | 0.966       | <0.001  | −4.661***       | 1.066       | <0.001  |
| Bid                                                                                                                                         | −0.053***    | 0.005       | <0.001  | −0.0528***      | 0.005       | <0.001  |
| <i>Socio-economic characteristics</i>                                                                                                       |              |             |         |                 |             |         |
| Hhsize                                                                                                                                      | −0.118       | 0.075       | 0.115   | −0.109          | 0.076       | 0.150   |
| Edu                                                                                                                                         | −0.027       | 0.174       | 0.876   | −0.020          | 0.172       | 0.908   |
| Income                                                                                                                                      | 0.792***     | 0.091       | <0.001  | 0.791***        | 0.091       | <0.001  |
| Age                                                                                                                                         | −0.001       | 0.008       | 0.916   | −0.001          | 0.008       | 0.891   |
| <i>Perceptions (WS, risk, climate, gender involvement, solutions to tackle WS in relation to management of blue, green water resources)</i> |              |             |         |                 |             |         |
| Severe                                                                                                                                      | 0.356**      | 0.170       | 0.036   | 0.344*          | 0.172       | 0.046   |
| Risk                                                                                                                                        | 0.195***     | 0.052       | <0.001  | 0.195***        | 0.053       | <0.001  |
| Climate                                                                                                                                     | 0.330**      | 0.138       | 0.017   | 0.302**         | 0.142       | 0.034   |
| Gendinvol                                                                                                                                   | 0.309*       | 0.169       | 0.067   | 0.305*          | 0.167       | 0.068   |
| LocaStore                                                                                                                                   | −0.145**     | 0.070       | 0.039   | −0.153**        | 0.074       | 0.040   |
| IrriTech                                                                                                                                    | 0.270 **     | 0.109       | 0.014   | 0.372*          | 0.223       | 0.095   |
| 1Must5Reduc                                                                                                                                 | —            | —           | —       | IV              | —           | —       |
| N                                                                                                                                           | 398          |             |         | 398             |             |         |
| Log pseudolikelihood                                                                                                                        | −163.798     |             |         | −575.137        |             |         |
| Pseudo R <sup>2</sup>                                                                                                                       | 0.3999       |             |         |                 |             |         |
| Wald $\chi^2$                                                                                                                               |              |             |         | 120.83***       |             | <0.001  |
| Montiel-Pflueger test                                                                                                                       |              |             |         |                 |             |         |
| Effective <i>F</i> —statistic                                                                                                               |              |             |         | 104.607         |             |         |
| C.I. alpha                                                                                                                                  |              |             |         | 5%              |             |         |

Notes: \*\*\*Significant level = 1%, \*\* Significant level = 5%, \*Significant level = 10%.  
1Must5Reduc was used as an IV in the IV-Probit model.

underlying mechanism, a higher concern or greater knowledge/appreciation of management of green water resources may lead to higher valuation for the water ES. It is indicated that the instrument (*1must5reduc*) has no influence on the outcome (WTP) except via the impacts of its influences on the treatment (IrriTech) which in turn affects the outcome (WTP). As a result, “*1must5reduc*” was adopted as an IV in the IV-Probit model. The results of the IV-Probit and Montiel-Pflueger test indicate that the effective *F*-statistic value is sufficiently large, demonstrating that the instrument is valid and strong enough to address endogeneity concerns, and the regression results are reliable (Montiel Olea and Pflueger 2013). Therefore, using the IV-Probit model and employing *1must5reduc* as an instrument is relevant for capturing/addressing the endogeneity inherent in the analysis.

From Table 6, the coefficient of the bid variable is statistically significant and negative, indicating that as bid levels increase, the probability of saying “yes”

decreases, which is consistent with the economic theory and results of previous studies (Ejeta *et al.* 2019; İkikat Tumer 2019; Khan and Zhao 2019; Kidane *et al.* 2019; Loomis *et al.* 2000). Socioeconomic background determines the WTP. Households with a higher income (affordability) are likely to have a higher probability of saying “yes”, which is in line with the past literature (Ejeta *et al.* 2019; Khan and Zhao 2019; Khan *et al.* 2019b; Kidane *et al.* 2019; Thapa *et al.* 2022; Wang *et al.* 2021). Similar to previous studies (Khan and Zhao 2019; Kidane *et al.* 2019; Stone *et al.* 2008; Tuan *et al.* 2014), we found no correlation between age, household size, education and payment probability.

Households who reported that WS had a significant impact on their income from rice farming had a greater likelihood of agreeing to pay. In addition, participants who perceived a greater risk of household damage from rice farming as a result of WS had a greater likelihood of approving the payment. An outstanding finding from this study is the positive correlation between the perception of climate change and WTP to mitigate WS. A higher probability of agreeing to pay for the water ES was found among those who believe that climate change will likely intensify the risk of WS in rice cultivation in the LMB. This is crucial since the impacts of climate change on WS in agricultural production in the LMB has become increasingly evident in terms of magnitude and severity. Households that hold a belief that climate change will likely exacerbate the risk of WS in rice farming in the LMB appear to support measures to reduce WS.

Interestingly, farmers who endorse that there is an agreement between women and men (who are the main or co-responsible) in accessing and using water for rice irrigation tend to have a higher probability of saying “yes”. Although this variable is only significant at 10%. Nevertheless, from a gender engagement perspective, this result somehow indicates that the mutual agreement between key partners, including women, in households is vital for supporting the measures aimed at tackling WS via ES approach. This finding signifies that there may be a certain level of collaboration between men and women in irrigation decision-making process, which underscores the importance of considering gender dynamics in households when designing and implementing measures to mitigate WS through the ES based mechanisms. Such results will be incorporated into our implications for further inclusion of the gender dimension in terms of tackling WS in rice production in the study area and for future studies.

The results indicate that farmers who hold the belief that investment in local water storage is a strategy to overcome WS are less likely to agree to pay. This finding could be attributed to households’ lack of awareness of the benefits of local water storage, nor do they have sufficient exposure or experience with its efficiency in addressing WS.

By contrast, farmers who believe that utilizing proper irrigation techniques (such as alternate wetting and drying — AWD) can contribute to addressing WS are likely to have a higher probability of approval for the WTP. These results indicate that pilot activities (such as AWD as a nature-based mechanism), can be adopted in these potential households to restore and improve water ES and tackle risks associated with WS.

### 4.3. Willingness to pay estimates

In order to examine the value of maintaining and restoring the provisioning and regulating ES associated with rivers and canals to support rice production in the study area, this study employed both parametric and non-parametric estimation techniques.

#### 4.3.1. Non-parametric estimation

A description of the WTP values based on non-parametric estimation is presented in Table 7. The results showed that the WTP was estimated at approximately VND225,430 per ha. The estimation for the total value of restoring and maintaining water-related ES under different WS scenarios in the study area are calculated by the areas likely affected by WS multiplying by the WTP per unit.

This study undertook a scenario analysis to estimate the total value of the restoration of water ES under various WS contexts. The underlying rationale for setting out the different scenarios was identified. It is reported that, the magnitude of the affected area of WS varies by month, ranging from 22% to 78% (Feb), 12% to 57% (May), 19% to 60% (June) (Minh *et al.* 2022). The influence of WS on rice production may also vary in magnitude across different cropping seasons, ranging from mild to moderate or severe. Furthermore, the impacts of climate change,

**Table 7.** WTP for the Restoration and Maintenance of the Water Related ES Associated with Rivers and Canals Upstream of the VMD to Support Rice Production

| Bid Levels<br>(VND/0.1ha) | Number of<br>Respondents (n) | Number of “yes”<br>Answer (Y) | Share of “yes”<br>Answers (Y/n) (%) | Midpoint Estimates<br>(VND/ha) |
|---------------------------|------------------------------|-------------------------------|-------------------------------------|--------------------------------|
| —                         | —                            | —                             | —                                   | 6,560                          |
| 5,000                     | 80                           | 59                            | 73.8                                | 10,870                         |
| 10,000                    | 81                           | 48                            | 59.3                                | 18,520                         |
| 20,000                    | 81                           | 38                            | 46.9                                | 51,450                         |
| 35,000                    | 78                           | 22                            | 28.2                                | 76,920                         |
| 55,000                    | 81                           | 9                             | 11.1                                | 61,110                         |
| Total                     | 401                          | 176                           | 43.9                                | 225,430                        |

saline water intrusion, and diminishing upstream flow are predicted to exacerbate WS and droughts, resulting in a significantly geographic expansion of affected areas (Minh *et al.* 2022). Therefore, it is assumed that due to climate change, decreased upstream flow, increased likelihood of WS occurrence, prolonged drying periods, and other issues that cause deficiency in water availability, the affected area by WS may vary from 10% to 80% of total land area in An Giang and Can Tho. This yields a total value of US\$3,469,603 in the scenario of a 10% affected area and US\$ 27,756,823 under the scenario of an 80% affected area in five years (Table A.1, Appendix A).

#### 4.3.2. Parametric estimation of the WTP

According to parametric estimates, the median WTP (Willingness to Pay) for the restoration and maintenance of water-related ecosystem services (ES) was VND18,830 per 0.1 ha or VND188,300 per 1 ha (Table A.2, Appendix A). Therefore, the total value of preserving water-related ES is US\$2,898,133 under the scenario of a 10% affected area and US\$23,185,068 under the scenario of an 80% affected area over a period of five years (Table A.3, Appendix A).

## 5. Discussion

Water demand in the VMD is forecasted to increase threefold to meet agricultural production needs (Minh *et al.* 2022; Smyle and Cooke 2014). In the context of climate change and diminishing upstream flow, the frequency and severity of WS are predicted to continue increasing (Minh *et al.* 2022). Therefore, nature-based solutions, such as the use of proper irrigation technique AWD, should be utilized, incentivized, and prioritized as valuable and practical complementary tools, in addition to human-based measures reflected in the *Global Commission on Adaptation* (2019). These nature-based solutions should be included in the national and local policy agenda to restore water flow, maintain water quality, and mitigate WS-related risks, aiming for effective and sustainable management of the river water basin.

Findings from this study suggest that farmers in the study sites are willing to contribute financially to the restoration and maintenance of water ES associated with rivers and canals, since they are aware of the beneficial values of provisioning and regulating services of water-related ES in support for rice production. The perception of severity of WS and its associated risk to rice farming are found to positively influence on the households' decisions to pay. Also, findings indicate that mutual agreement between key partners, including women, in households is vital for supporting the measures aimed at tackling WS via ES approach. Hence, it

is crucial to foster the mutual collaboration between men and women in decision-making processes and other collective actions. The enhancement of women's participation in the management of water resources has been proved to lead to better outcomes in tackling water-related issues (Khandker *et al.* 2020). However, in many regions, women are disproportionately disadvantaged in adaptive capacity owing to barriers in capital, knowledge, information, and time (Imburgia 2019). Hence, it is crucial to improve the knowledge and skills of women, increase the involvement of women in water management, empower women in decision-making process, in order to help water management/conservation practices more inclusively and resiliently.

While previous studies have primarily evaluated the farmers' perceptions of climate change and its associated impacts on cultivation, our study adds further contribution by exploring the WTP of local rice farmers for the restoration of water-related ES capturing the respondents' beliefs about future impacts of climate change. Since the impacts of climate change are becoming more severe, households who believe about increased risk of WS on rice farming in the future owing to climate change-driven causes are likely to value more for water-related ES. Since households are more inclined to place greater value on the restoration of water-related ES, it appears that local farmers start to have growing understanding of the severity of future climate impacts on water resources for rice production. In response to climate change adaptation, policies should create an enabling environment to support nature-based measures as coping strategies to tackle WS, enhance the provision of water-related ES, and empower local communities' adaptive capacity to mitigate risks associated with WS (Seddon *et al.* 2020).

Furthermore, farmers in ancient periods have been known to utilize a variety of water sources, ranging from blue to green water resources, to fulfill diverse water requirements including those for agricultural purposes and combat water scarcity and challenging ecological conditions (Vidal *et al.* 2010). While many studies have focused on measures and solutions to improve blue water (e.g., surface water) in rice cultivation, green water (e.g., soil water storage) has not received considerable attention (Mao *et al.* 2020). It is highlighted that, green water, a vital and scarce resource, should be incorporated into any evaluation of strategies to cope with water scarcity (Schyns *et al.* 2019). Very few studies have incorporated the management of blue and green water resources in their valuation of water-related ES to address WS. The results of this study prove that farmers who believe in investing in irrigation techniques, such as alternate wetting and drying (AWD), have a higher valuation of water-related ecosystem services (ES) that address water scarcity (WS) in rice production. These findings suggest that enhancing green water resources, such as improving irrigation methods, can be one of the

preferences and priorities in the process of restoring water ES services and coping with WS. Additionally, since rice farmers indicate their value or preference for the maintenance and restoration of water ES, supporting nature-based solutions like AWD can contribute to increasing the supply of water ES, as these interventions align with what farmers value or prefer. Therefore, nature-based mechanisms among rice farming households should be prioritized in pilot initiatives to improve water ES and overcome WS, with consideration for their application to wider communities.

We acknowledge the limitations of the CVM approach, in which hypothetical bias is the most common problem. To reduce the drawbacks of hypothetical bias in this study, the scenario presentation was carefully prepared and revised several times from the early phase in collaboration and consultation with stakeholders until survey implementation. This process included cognitive interviews, FGDs, pilot surveys, and main surveys to ensure the validity and credibility of the scenario. Participants were informed that the results of the study would be shared with local authorities and passed on to relevant decision makers, which made the hypothetical payment real and guaranteed incentive compatibility in their responses. Cheap talk scripts were also used to reduce hypothetical bias and provide participants with a context close to a real market situation.

To avoid information and embedding effects, the study sites are contextualized, and the values provided by the preservation of water-related ecosystem services (ES) are defined in the scenario. Question-order bias is prevented through careful testing and revision of the questionnaires using focus group discussions (FGDs) with stakeholders and pilot surveys. Starting point bias is eliminated by conducting FGDs with relevant stakeholders, including the local community, local authorities, experts, pilots, and revisions of the bid levels. Interviewer bias is mitigated through rigorous selection and thorough training of interviewers. Strategic bias is significantly reduced by adopting a single-bounded dichotomous (SBDC) willingness to pay (WTP) question format (OECD 1995). This format, used in other contingent valuation method (CVM) studies (Hoa and Ly 2009; Tuan *et al.* 2014), helps reduce potential associated biases.

## 6. Conclusions

The study employed the contingent valuation method to estimate the value of water-related ecosystem services (ES) in Vietnam, specifically focusing on provisioning and regulating services that address water scarcity (WS) in rice farming. By incorporating gender and climate change perceptions, this study built upon the current literature regarding the valuation of river ecosystem services associated

with provisioning and regulating benefits. The aim was to provide an updated understanding of the value of water resources and to enhance water governance in agricultural production.

The study findings revealed that a substantial number of surveyed households have faced severe water scarcity in the past five years. Over 70% of respondents reported occasional or regular experiences of water scarcity within the last 12 months. These statistics underscore the growing risk of water scarcity in rice production at the household level. Furthermore, the study identified that rice farmers are willing to embrace coping measures and preventive practices to restore and preserve water-related ecosystem services in rivers and canals. This recognition highlights the importance of these services in sustaining rice cultivation.

Nature-based coping mechanisms, such as improved irrigation techniques, have gained attention within communities as effective means of enhancing water-related ecosystem services. The study confirms that farmers in the study sites are willing to contribute financially to the restoration and maintenance of water-related ecosystem services associated with rivers and canals. They recognize the beneficial values of these services in supporting rice production. Parametric estimates reveal a median willingness to pay (WTP) of VND188,300/ha for the restoration and maintenance of water-related ecosystem services. The total value of preserving these services is estimated at US\$2,898,133 for a 10% affected area and US\$23,185,068 for an 80% affected area over a five-year period. The perception of water scarcity severity and its associated risk to rice farming was found to positively influence households' decisions to contribute financially. Additionally, the study demonstrates that involving women in water resource management leads to better outcomes in addressing water-related issues. Therefore, it is essential to consider farmers' perceptions, gender preferences, and associated WTP values when formulating water policies.

To advance knowledge in this field, future studies should explore farmers' preferences for adopting nature-based solutions to improve and conserve water-related ecosystem services in rivers within the basin. Furthermore, it is crucial to investigate farmers' perceptions and practices regarding the utilization of the blue-to-green water continuum and various water sources to enhance water productivity and address challenges posed by water scarcity. Additionally, understanding farmers' and stakeholders' priorities concerning the allocation and utilization of green water flows between agricultural activities and ecosystem needs, from different viewpoints, including gender perspectives, can help develop effective strategies for conserving green water resources and promoting sustainable water use in agriculture. Filling these gaps in the literature will significantly contribute to our understanding and valuation of water-related ecosystem services. The results of

this study not only emphasize the value of restoring water-related ecosystem services but also provide valuable insights and policy implications for relevant stakeholders. These findings can assist in developing effective coping strategies and preventive measures against water scarcity in the area, ultimately enhancing water-resilient agriculture in the Lower Mekong Basin.

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Appendix A

Table A.1. Aggregation of WTP for the Different Scenarios (Non-Parametric Estimates)

| Scenario of Area Affected by WS (%)                |  |            |             |             |             |             |             |             |             |
|----------------------------------------------------|--|------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
|                                                    |  | 10%        | 20%         | 30%         | 40%         | 50%         | 60%         | 70%         | 80%         |
| Total area affected by WS (2019) (ha) <sup>1</sup> |  |            |             |             |             |             |             |             |             |
| An Giang                                           |  | 62,000     | 124,000     | 186,000     | 248,000     | 310,000     | 372,000     | 434,000     | 496,000     |
| Can Tho                                            |  | 8,799      | 17,598      | 26,396      | 35,195      | 43,994      | 52,793      | 61,592      | 70,390      |
| WTP (VND/year)                                     |  |            |             |             |             |             |             |             |             |
| An Giang                                           |  | 13,976,660 | 27,953,320  | 41,929,980  | 55,906,640  | 69,883,300  | 83,859,960  | 97,836,620  | 111,813,280 |
| Can Tho                                            |  | 1,983,513  | 3,967,027   | 5,950,540   | 7,934,054   | 9,917,567   | 11,901,081  | 13,884,594  | 15,868,108  |
| Total                                              |  |            |             |             |             |             |             |             |             |
| In 1 year in VND                                   |  | 15,960,173 | 31,920,347  | 47,880,520  | 63,840,694  | 79,800,867  | 95,761,041  | 111,721,214 | 127,681,388 |
| In 1 year in US\$                                  |  | 693,921    | 1,387,841   | 2,081,762   | 2,775,682   | 3,469,603   | 4,163,524   | 4,857,444   | 5,551,365   |
| In 5 years in VND                                  |  | 79,800,867 | 159,601,735 | 239,402,602 | 319,203,470 | 399,004,337 | 478,805,205 | 558,606,072 | 638,406,939 |
| In 5 years in US\$                                 |  | 3,469,603  | 6,939,206   | 10,408,809  | 13,878,412  | 17,348,015  | 20,817,618  | 24,287,221  | 27,756,823  |

Notes: <sup>1</sup>Total area of rice cultivation in An Giang in 2019 was 620,000ha; the total area of rice cultivation in Can Tho in 2019 was 87,988ha. The WTP per hectare was derived from Table 7. Exchange rate:1US\$ = 23,000VND (2022).

Table A.2. Estimated WTP (Parametric Estimates)

| Items                     | 1,000VND per 0.1ha |
|---------------------------|--------------------|
| Mean/Median WTP           | 18.83              |
| Krinsky & Robb (95% C.I.) |                    |
| Lower bound               | 15.70              |
| Upper bound               | 21.93              |

Notes: *N* = 398, C.I.: Confidence Interval, Number of reps: 10,000.

**Table A.3.** Aggregation of WTP for the Different Scenarios (Parametric Estimates)

|                                                    | Scenario of Area Affected by WS (%) |             |             |             |             |             |             |             |
|----------------------------------------------------|-------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
|                                                    | 10%                                 | 20%         | 30%         | 40%         | 50%         | 60%         | 70%         | 80%         |
| Total area affected by WS (2019) (ha) <sup>1</sup> |                                     |             |             |             |             |             |             |             |
| An Giang                                           | 62,000                              | 124,000     | 186,000     | 248,000     | 310,000     | 372,000     | 434,000     | 496,000     |
| Can Tho                                            | 8,799                               | 17,598      | 26,396      | 35,195      | 43,994      | 52,793      | 61,592      | 70,390      |
| WTP (VND/year)                                     |                                     |             |             |             |             |             |             |             |
| An Giang                                           | 11,674,600                          | 23,349,200  | 35,023,800  | 46,698,400  | 58,373,000  | 70,047,600  | 81,722,200  | 93,396,800  |
| Can Tho                                            | 1,656,814                           | 3,313,628   | 4,970,442   | 6,627,256   | 8,284,070   | 9,940,884   | 11,597,698  | 13,254,512  |
| Total WTP                                          |                                     |             |             |             |             |             |             |             |
| In 1 year in VND                                   | 13,331,414                          | 26,662,828  | 39,994,242  | 53,325,656  | 66,657,070  | 79,988,484  | 93,319,898  | 106,651,312 |
| In 1 year in US\$                                  | 579,627                             | 1,159,253   | 1,738,880   | 2,318,507   | 2,898,133   | 3,477,760   | 4,057,387   | 4,637,014   |
| In 5 years in VND                                  | 66,657,070                          | 133,314,140 | 199,971,211 | 266,628,281 | 333,285,351 | 399,942,421 | 466,599,491 | 533,256,562 |
| In 5 years in US\$                                 | 2,898,133                           | 5,796,267   | 8,694,400   | 11,592,534  | 14,490,667  | 17,388,801  | 20,286,934  | 23,185,068  |

Notes: <sup>1</sup>Total area of rice cultivation in An Giang in 2019 was 620,000ha; the total area of rice cultivation in Can Tho in 2019 was 87,988ha. The WTP per hectare was derived from Table A2. Exchange rate:1US\$ = 23,000VND (2022).

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