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Perceptions and willingness to pay for water management on a highly developed tourism island under climate change: A Bayesian network approach

Thuc D. Phan[a,b,*], Edoardo Bertone[a], Tien D. Pham[c], Tuyen V. Pham[d]

[a] Cities Research Institute, Griffith University, Gold Coast, Queensland 4215, Australia
[b] Institute of Research and Development, Duy Tan University, Da Nang 550000, Viet Nam
[c] Griffith Institute for Tourism, Griffith University, Nathan, Queensland 4111, Australia
[d] Cat Ba Biosphere Reserve Office, Cat Ba Island, Hai Phong 180000, Viet Nam

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ABSTRACT

Water resources management in the coastal and island tourism destinations faces many challenges and threats driven by climate change and socio-economic stressors, especially in developing countries. Understanding the perceptions of a range of stakeholders, including tourism providers, on the perceived importance of water resources management subject to climate change and tourism development in these destinations is, therefore, needed for a long-term strategy satisfying a growing water demand from socio-economic development. This study applies both logistic regression models and Bayesian networks to explore the determinants affecting the respondents' perceptions and willingness to pay (WTP) for building reservoirs and increasing water price on Cat Ba Island, Vietnam subject to climate change and tourism development. Our findings show that about 83.5% of respondents are willing to contribute to the construction of reservoirs, while only 26.2% of respondents are supporting higher water prices in the island. Climate change and tourism development were found to be the strongest factors causing water shortage and in turn affecting the respondents' WTP for building reservoirs and increasing water price, followed by occupation and monthly income. Such perceptions and experiences of a variety of stakeholders on the nexus of tourism development, water resources management and climate change can contribute to formulating policies and decision-making support, thereby potentially strengthening the tourism industry, and protecting the water resources under climate change on Cat Ba Island.

1. Introduction

Management of water resources faces many challenges, often from the combined pressures of climate change, socio-economic stressors and demands from multiple stakeholders in many regions across the world. Changes in precipitation, increased temperature, and sea level rise, coupled with socio-economic stressors are considered as major drivers for water scarcity, making it increasingly challenging for managers to satisfy growing water demands from different water users (Phan et al., 2019a; Barnett et al., 2020). This is of particular concern for highly developed tourism islands in developing countries (Gössling et al., 2006; Deyà Tortella and Tirado, 2011).

Water resources management, tourism development and climate change in such islands present an interrelated and interconnected system. Tourism activities are dependent on freshwater resources, and both are strongly driven by climate change (Gössling et al., 2006; Enriquez et al., 2017; Cole, 2012). Therefore, they should be examined together to improve water management and given underpinning tourism industry and climate change. However, the nexus of these factors for famous tourism islands has been rarely investigated in the literature, with only two of them were simultaneously considered, such as tourism and water resource in Bali, Indonesia (Cole, 2012), water resource and climate in Santorini Island, Cyclades (Enriquez et al., 2017), tourism and climate in Zanzibar Island, Tanzania (Gössling et al., 2006), and in Mediterranean tourist coastal areas (March et al., 2014).

A multi-dimensional stakeholder involvement is necessary in water resources management, as it provides a comprehensive range of critical and practical perspectives concerning all water users. These perceptions are one of the essential steps in planning water conservation programs, especially in assisting decision-makers to develop efficient policies (Halkos and Matsiori, 2016). Multi-dimensional stakeholders' willingness to support for water resources management is strongly

* Corresponding author at: Cities Research Institute, Griffith University, Gold Coast, Queensland 4215, Australia
E-mail address: pduythuc@gmail.com (T.D. Phan).

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influenced by the effectiveness of the current water resources management policies, scarce water resource status and the level of knowledge among residents and their individual attribution (Barnett et al., 2020). Understanding the multi-dimensional stakeholders' perceptions on the management of the island's scarce water resources through measuring willingness to pay (WTP) is, therefore, needed for a long-term strategy to meet a growing water demand coming from socio-economic development.

Several statistical analysis methods have been used to identify factors affecting the respondents' perceptions on the management of water resources, including an ordered probit model (Cooper et al., 2019), structural equation modeling (Glenk and Fischer, 2010), logit models (Gebretsadik and Romstad, 2020; Keough and Vásquez, 2020), logistic regression and multiple linear regression models (Halkos and Matsiori, 2016) and generalised linear model (Barnett et al., 2020). Bayesian networks (BNs) were also initially applied by Peng et al. (2018) to identify the influential factors on respondents' WTP on water diversion project in Beijing. BNs are probabilistic graphical models which provide decision makers with a transparent tool for exploring the combined effects of interacting drivers (e.g., monthly income, genders) on the outcome variables (e.g., respondents' WTP), promoting system learning and assisting decision-making support (Phan et al., 2019a; Peng et al., 2018; Jensen and Nielsen, 2007). The accurate performance and applicability of these modeling methods are essential for the decision-making process. In situations where there are multiple interacting drivers, subjective decision making by human actors and high levels of uncertainty and complexity, the prediction accuracy of BNs in water management has been shown to be superior to other methods, such as logistic regression, multiple linear regression, and structural equation models (Panidhapu et al., 2020). Although BNs have been widely applied as a decision support tool in water resources management problems affected by multiple changes (Phan et al., 2019a), our review of current literature shows that BNs have been very rarely applied to determine determinants affecting respondents' perceptions and WTP for improved management of scarce water resources in highly developed tourism islands in climate change conditions.

This paper aims to determine the multi-dimensional stakeholders' perceptions and WTP for improved management of scarce water resource on Cat Ba Island. Specifically, this present study (1) investigates perceptions of different stakeholders on the nexus of scarce water resources management, tourism development and climate change on the island, (2) develops logistic regression models to quantify the correlations between dependent and independent variables, and (3) develops Bayesian Networks to examine the different perceptions and determinants affecting respondents' WTP for building reservoirs and higher water prices. The results of this study could help decision-makers adapt more effective practices to the sustainable development of water resources, thereby strengthening the tourism industry under climate change on Cat Ba Island.

2. Case study – Cat Ba island

Cat Ba is the largest island of the Cat Ba Archipelago in Hai Phong City in northern Vietnam (Fig. 1), which has been recognised as a World Biosphere Reserve by the United Nations Educational, Scientific and Cultural organization since 2004. Cat Ba Island has a large degree of diversity of landscape and ecosystems with more than forty white sandy beaches integrated with natural limestone forests and rocky cliffs. It is comprised of six communes and one town with a population of 18,789 people in 2018 (Cat Hai Division of Statistics (CHDS), 2019).

The island is one of the most beautiful places in Vietnam and has become a preferred destination for tourists from all parts of Vietnam as well as from around the world. As a result, the number of tourists to the island has increased by about 2% per year over the last decades and reached 3,158,000 tourists in 2018 (Fig. 2), leading to substantial development of facilities, with a total of 225 hotels and guest houses and 65 restaurants in 2018 on the island (Cat Hai Division of Statistics (CHDS), 2019). In addition, the island's population increases 1% per year due to the high birth rate and influx of migrants and reached 18,789 people in 2018 (Cat Hai Division of Statistics (CHDS), 2019). High population growth and tourism development are the two main driving forces that

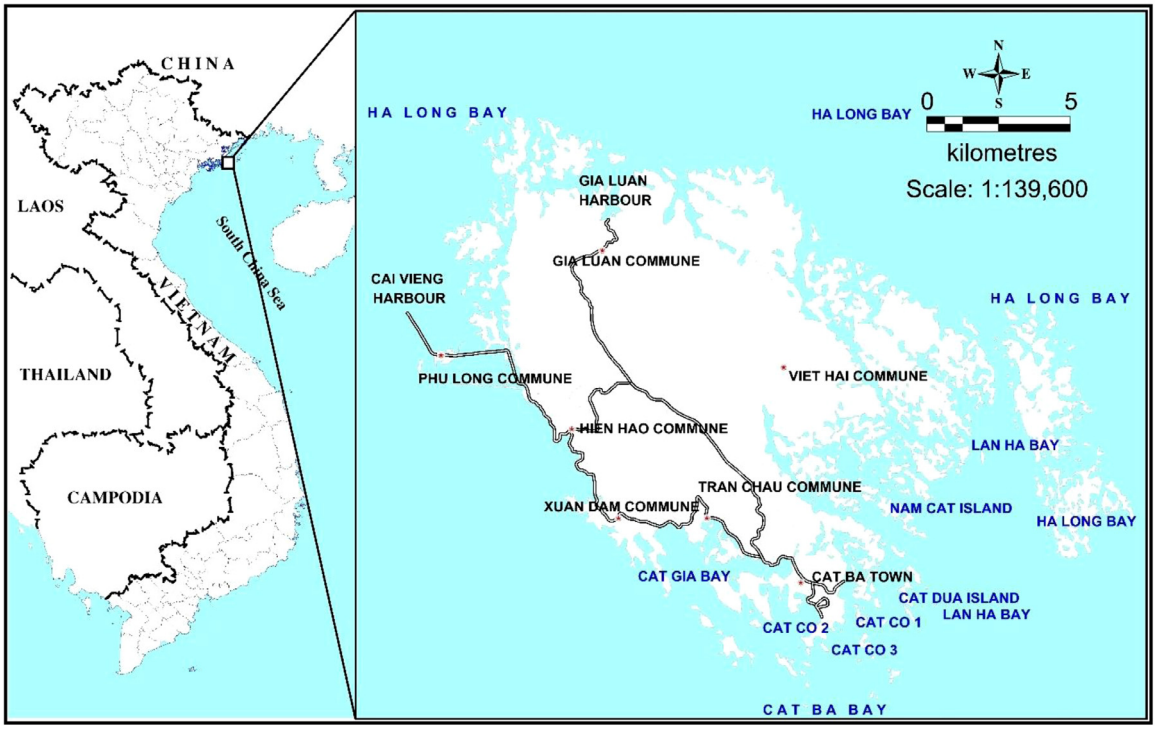

Fig. 1. Map of Cat Ba Island.

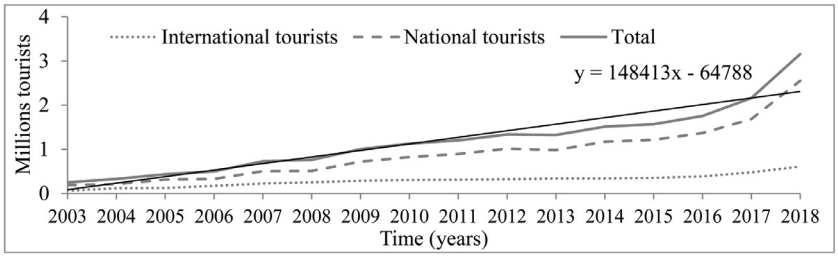

Fig. 2. Tourists visiting Cat Ba Island from 2003 to 2018 (Cat Hai Division of Statistics (CHDS), 2019).

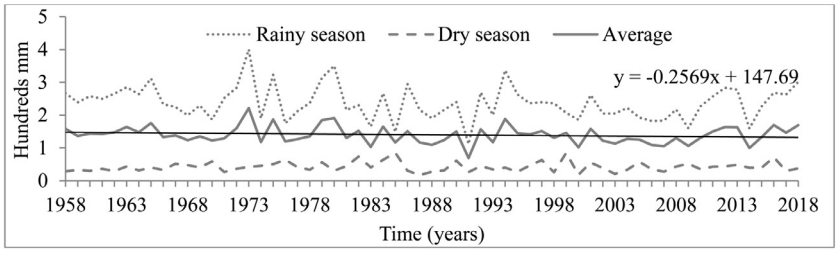

Fig. 3. Precipitation in the Cat Ba Island over a 61-year period, from 1958 to 2018 (National Northeast Meteorological and Weather Stations (NNMWS), 2019).

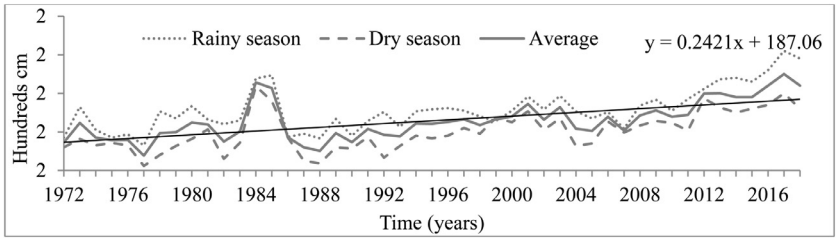

Fig. 4. Sea level in Hon Dau Station, Hai Phong over a 47-year period, from 1972 to 2018 [18].

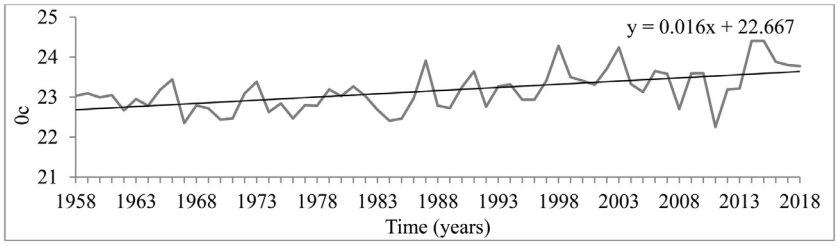

Fig. 5. Average temperature in Hai Phong region over a 61-year period, from 1958 to 2018 (National Northeast Meteorological and Weather Stations (NNMWS), 2019).

have pushed up demand for freshwater significantly over time on Cat Ba Island.

As a consequence of such development, the island faces many challenges in terms of water resources management. Water supply sources of Cat Ba Island consist of wells, reservoirs, and household rainwater tanks, which are strongly dependent on the interactions between local precipitation, sea level and temperature. Historical data showed that these factors have adversely changed in the Hai Phong Region. Over a period of 61 years, from 1958 to 2018, precipitation in the Haiphong region had decreased nearly 5.8% (Fig. 3) and during a shorter period of just 47 years between 1972 and 2018, sea level had risen by 20 cm Fig. 4. Temperature also increased about 2 °C to 5 °C over a 61-year period (Fig. 5). These changes, coupled with high rates of population growth and tourism development have caused to high water shortages in the last several summers in the Cat Ba Island, especially in the summers of 2016, 2017 and 2018 (Cat Hai Water Supply Plant (CHWSP), 2019).

Recently, Ministry of Natural Resources and Environment (MONRE) (2016) has projected further changes of these climate variables by 2050 based on the Fifth Assessment Report of Intergovernmental Panel on Climate Change (IPCC) under RCP 4.5 and RCP 8.5 in 2013, specifically indicating a further 10% reduction of precipitation, a further sea level rise between 14 cm and 36 cm, and temperature increase of about 5 °C to 7 °C. The interactions among these factors will affect the water availability in the island's drilled and dug wells, household water tanks and reservoirs. Given water shortages were already experienced in recent summers as result of past changes, water shortages are expected to be worsened over the coming decades by further expected climate changes and population growth, thereby constraining socio-economic development for the island. Therefore, it is imperative to consider policy options to address the water shortage issues for Cat Ba Island.

3. Material and methods

This study applied both logistic regression models with model averaging and Bayesian networks, which have been successfully applied to support the wildlife conservation (Phan et al., 2019b), to explore the determinants affecting the respondents' perceptions and willingness to pay (WTP) for building reservoirs and increasing water price on Cat Ba Island subject to climate change and tourism development. The modeling diagram of this study was illustrated as Fig. 6 and further explained in the following sections.

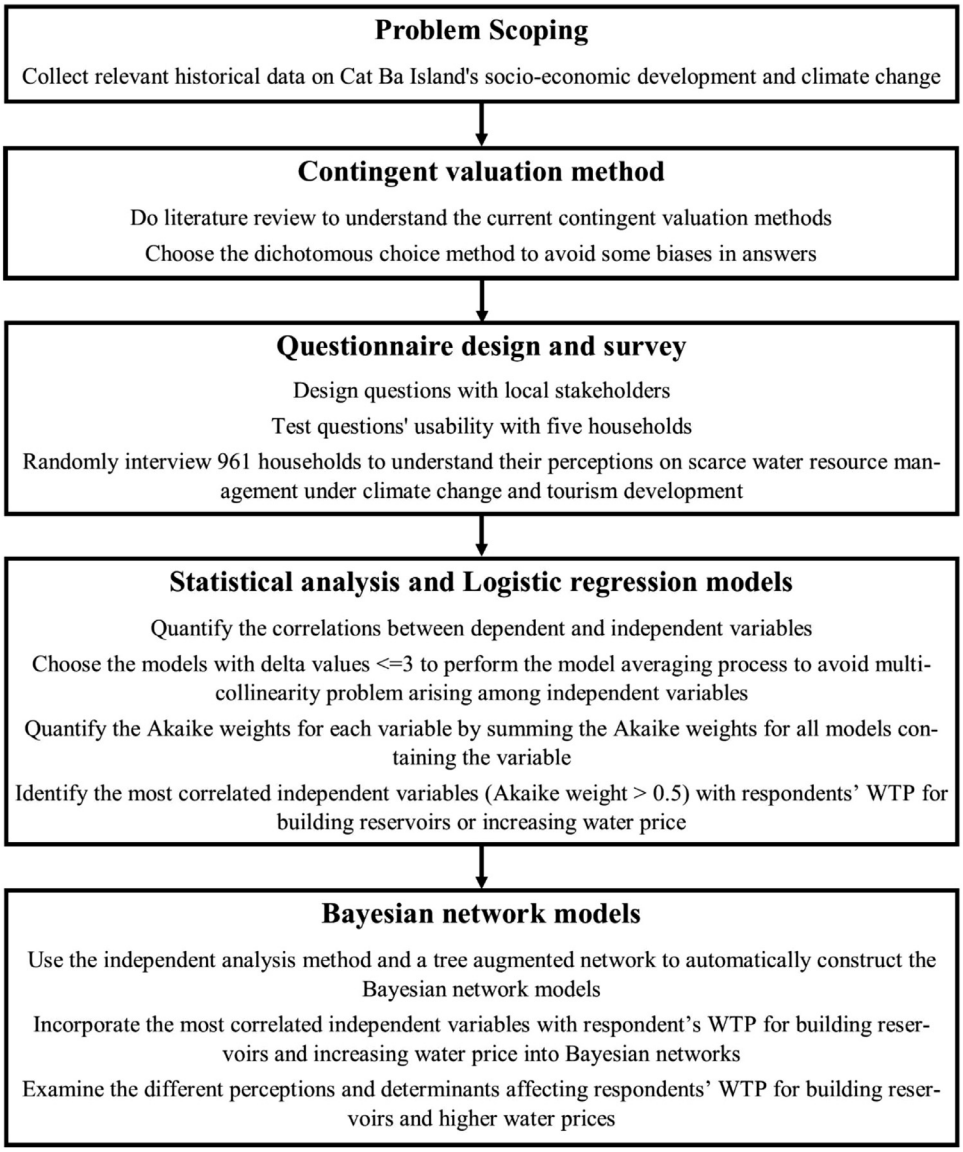

Fig. 6. A proposed methodological flowchart.

3.1. Contingent valuation method

The contingent valuation method (CVM) is a survey-based approach, in which an individual independently states his or her willingness to pay for the management of environmental services in a particular location (Mitchell and Carson, 1990). Using the contingent valuation on the basis of willingness to pay (WTP) to reveal the preferred approaches to managing water resources has become more prevalent during the last few decades, and applications include artificial lake management (Halkos and Matsiori, 2016), groundwater management (Brouwer et al., 2018), water restriction management (Cooper et al., 2019), and flood management (Glenk and Fischer, 2010).

There are several CVM elicitation methods available in the literature (e.g., direct or open-ended, dichotomous choice, bidding game and payment card), and each of them has advantages and disadvantages (Cooper and Loomis, 1992; Boyle et al., 1996). In this study, the dichotomous choice method was chosen to avoid some biases in answers (Cooper and Loomis, 1992). Respondents were asked to choose a single value within a proposed list of five values for their willingness to support for building reservoirs and/or higher water prices, and the selected value represents the respondent's WTP.

3.2. Questionnaire design and survey method

Interviews were conducted with local stakeholders (including hotel and restaurant owners) in six communes and one town on Cat Ba Island to understand their perspectives on the management of scarce water resource for the island under high levels of climate change and tourism development. The questionnaire was designed in conjunction with twelve representatives of local stakeholders (e.g., decision-makers, water managers, water users and climate change experts) from Hai Phong City and Cat Ba Island through three focus group discussions on February 2019. The questionnaire was finalised with questions as simple and clear as possible to make sure that all respondents can understand them, and we then randomly chose five households in Viet Hai commune to test the questionnaire's usability, with only minor changes were made to the questionnaire.

The final questionnaire consisted of four sections. The first section aimed to obtain information on socio-demographic characteristics of the households, such as gender, age, education, occupation, household size, residence place, residence, and income. In the second section, respondents were asked general water consumption information, such as water use sources (e.g., water supply plant, dug wells or household rainwater

Table 1
Descriptions of variables used in statistical analysis and Bayesian networks.

Variable	Description
Dependent variable	
Increasing water price	Respondents' willingness to pay for increasing water price: 1 = Yes WTP, 0 = No WTP
Building reservoirs	Respondents' willingness to pay for building more reservoirs: 1 = Yes WTP, 0= No WTP
Independent variable	
Gender	Gender of respondents: female = 1, male = 0
Age	Category of respondents' age: from 1 = 18 to 26 years, 2 = 27 to 36 years, 3 = 37 to 46 years, 4 = 47 to 56 years, 5 = 57 years and above
Education	Category of respondents; education: from 1 = primary school, 2 = secondary school, 3 = high school, 4 = technical education, 5 = university and postgraduate
Occupation	Occupation of respondents: 1= tourism sector (hotel and restaurant owner, trader, shop owner), 2 = causal labor, 3 = farmer, 4 = housewife, 5 = government officer, 6 = retired, 7 = hired labor, 8 = aquaculture
Household size	Number of family members: 1 = 1 to 2 persons, 2 = 3 to 4 persons, 3 = 5 to 6 persons, 4 = 7 to 8 persons
Residence place	Place of residence: 1 = Cat Ba Town, 0 = other communes
Residency	Residency of respondents: 1 = permanent, 0 = temporary
Monthly income (USD)*	Monthly income of respondents: 1 = 0 to 500, 2 = 501 to 1000, 3 = 1000 to 2500, 4 = 2501 and above
Water use sources	Water use from different sources: 1 = use from one source, 2 = use from two sources; 3 = use from three sources
Average monthly water use	Total average monthly water use (m^3) from household: 1 = 1 to 10 m^3, 2 = 11 to 20 m^3, 3 = 21 to 40 m^3, 4 = 41 to 60 m^3, 5 = 61 m^3 and above
Climate change impacts	Respondent attitudes toward the impacts of climate change on water resources: 1= strongly agree, 2 = agree, 3 = no opinion, 4 = disagree, 5 = strongly disagree
Tourism development	Respondent attitudes toward the tourism development on water resources: 1= strongly agree, 2 = agree, 3 = no opinion, 4 = disagree, 5 = strongly disagree

* US$1 is equivalent to VND 23,273 on 30th May 2019.

tanks) for daily activities and tourism activities, and average monthly water uses from these sources. In the third section, respondents were asked about their perspectives on the relationships between water management, tourism development and climate change on the island. The terms related to climate change (e.g., sea level rise and precipitation decline) and socio-economic development (e.g., population growth and tourism development) were discussed by providing examples of historical data on changes in sea level, temperature, precipitation and population and tourism numbers in the island over time to help respondents understand how these changes effects on the management of water resources. Water shortage management was the last section of the questionnaire, exploring the respondents' WTP for the water security management in the context of climate change and tourism development on Cat Ba Island. Respondents were then asked whether they agreed or disagreed to pay for an increase in water price and/or contribute to the construction of reservoirs. They were also asked to give reasons for their answers. Building reservoirs are considered as a long-term policy option, addressing the supply side directly while accepting higher water prices reflects a short-term policy option, dealing with water demand side management.

Sloven's formula (Altares et al., 2003) was used to determine the desired number of respondents selected for interview as presented Eq. (1).

$$n = \frac{N}{1 + Ne^2} \quad (1)$$

where n is a sample size, N is a total number of households on Cat Ba Island and e is desired margin of error.

There were 18,789 people corresponding to 4902 households in 2018 (Cat Hai Division of Statistics (CHDS), 2019), located in Cat Ba town and six communes on Cat Ba Island. An acceptable margin of error used by most survey researchers typically falls between 4% and 8% at the 95% confidence level (Altares et al., 2003). However, we wanted to have a tighter accuracy and thus we chose a designed margin error of 3% for this study. As a result, a total sample size of 961 households was selected and accounted for 20% of the total households in each commune and town. These respondents were then randomly interviewed, face-to-face, from 9th March to 30th May 2019.

3.3. Statistical analysis

Data for both dependent and independent variables of respondents' WTP on the management of the Cat Ba Island's scarce water resources is listed in Table 1. The dependent variables are the 'yes' or 'no' answers of respondents to payment for the bid levels of building reservoirs and increasing water price, and they were assigned as binary values of 0 and 1, where 0 denotes unwillingness and 1 reflects willingness to pay. The list of independent variables includes the socio-economic characteristics and respondents' perceptions on influences of climate change and tourism development on the management of the island's scarce water resources (Table 1). The independent variables were also defined as either binary value of 0 and 1 (e.g., gender, resident place) or ordinary values (e.g., climate change, tourism development).

A statistical analysis method of generalised logistic models with model averaging described by Burnham and Anderson (2002) was applied to quantify the correlations among variables and select the most correlated independent variables using RStudio program version 1.1.463 (RStudio Inc.). The significant level of the Spearman's pair-wise correlation among 14 variables (two dependent variables and 12 independent variables) was evaluated to quantify the relationships between dependent variables and independent variables, and among independent variables. Chi-squared tests were also conducted using Chisq.test function in RStudio to identify the difference in respondents' perceptions between WTP for building reservoirs and higher water prices.

The relationships between dependent variables and independent variables were further examined using logistic regression models with model averaging to avoid multi-collinearity problem arising among independent variables. All model combinations generated from the logistic regression models was compared and the models with delta values of ≤ 3 were chosen to perform the model averaging process. Akaike weight of each variable was then quantified by summing the Akaike weights for all models containing the variable (Burnham and Anderson, 2002). Finally, the variables which have strong correlations with respondents' WTP for building reservoir or increasing water price (Akaike weights >0.5), were selected to incorporate into Bayesian networks.

3.4. Bayesian network model development

A Bayesian network (BN) is a probabilistic and graphical model that can be used for predicting the probability of an outcome of interest from known variables (Pearl, 1986). A BN consists of two main model components: (1) a directed acyclic graph (DAG), which denotes dependencies and independencies between variables, and (2) conditional probability tables (CPTs), which specify the relationships between those variables (Jensen and Nielsen, 2007). Each variable, defined as a node in the BN, has a set of states, and the probability of each state of a node is dependent on the states of the parent node(s). These probabilities are defined

by the CPTs, which may be derived using qualitative data (e.g., expert knowledge and stakeholder beliefs) and/or quantitative data (e.g., field data and modeling results).

Two approaches are commonly used to construct and train the BNs: (1) the automatic method and (2) the manual method. The first method uses algorithms to calculate the optimum structure of a training data set and to develop CPTs for variables in the model. Two broad classes of algorithms in the first method are mainly used for learning the structure of BNs: score-based functions and independent analysis (Cooper and Herskovits, 1992). The second method involves the elicitation of expert or stakeholder knowledge to identify which variables in a system are related and how strongly. In this study, the first approach, specifically the independent analysis method was used to construct the BNs to increase the network structure transportability and computational efficiency through two steps: (1) conducting correlation analysis among variables and removing the variables with weak correlations, (2) using a tree augmented network (TAN) to automatically develop the BN models' structure by learning the dataset of strongly correlated variables. The TAN classifier was chosen in this study because it significantly outperformed the Naïve Bayes and general Bayesian network classifiers in terms of classification accuracy in previous related studies (Friedman et al., 1997; Sahin et al., 2019).

Two separate BN models were formulated to analyze determinants of the two proposed management instruments (i) building reservoirs and (ii) increasing water price using Netica Software (Norsys, Inc). The target nodes (WTP for building reservoirs or increasing water price) have two states (yes, no), while other nodes have two states or more depending on categories as outlined in Table 1. The most correlated independent variables (Akaike weight >0.5) with respondents' WTP for building reservoirs or increasing water price were used to build these two BN models, learning the TAN structure. Following the construction of the BN models, the conditional probability tables for these nodes in these two models were determined from interviewed data.

3.5. Model evaluation

The evaluation of BNs helps ensure the model's interactions and outcomes are feasible and defensible and this is one of the important steps in learning a BN. In this study, prediction performance metrics were calculated to evaluate the accuracy of these two BN models. The k-fold cross-validation method (Boyce et al., 2002) was applied to evaluate the prediction performance of BN models. The dataset was divided into equally sized k sets ($k = 10$). One set of these k sets was used as a validation data, and the remaining k-1 sets were used as a training data for parameterising the BN models. The training and testing process of these two BN models was repeated until all ten sets were used. The results of these cross-validation tests were used to populate the confusion matrix (Table 6). The overall accuracy, sensitivity, specificity, and precision were calculated using the confusion matrix to give an insight on the performance of model predictions. These criteria are measured on the scale from 0 (worst classification) and 1 (perfect classification) using the following equations.

$$4.Sensitivity = \frac{TP}{(TP + FN)} \quad (2)$$

$$5.Specificity = \frac{TN}{(TN + FP)} \quad (3)$$

$$6.Accuracy = \frac{(TP + TN)}{(TP + TN + FP + FN)} \quad (4)$$

$$7.Precision = \frac{TP}{(TP + FP)} \quad (5)$$

Where: TN (True Negative), FP (False Positive), FN (False Negative), TP (True Positive)

In addition, sensitivity analysis was conducted in the BNs to determine the degree to which variation in posterior probability distributions is explained by other variables. The degree of variation in a target node (WTP) based on the variation of an input node (e.g., monthly income) characterises the importance of that input variable. The variance reduction was calculated as an expected reduction in the variation of the expected real value of the target node (e.g., WTP node with two states), due to the value of an input variable (e.g., water use sources with three states).

4. Results

4.1. Descriptive statistics of the respondents

The socio-demographic characteristics of the respondents are presented in Table 2. As gender equality was important in the data collection, we attempted to maintain an equal number of male and female interviewees. However, the final number of female participants (56% of the 961 respondents) was slightly larger than that of male participants. This over representation of females in the present sample could be related to the fact that women are often more exposed to water issues than men as women tend to be responsible for all activities of the housework for their families such as daily cooking and washing. In contrast, men are responsible for working outside and generally contributing to the main income for their families. This is prevalent in the north coast of Vietnam and thus women were more responsible and representative of their families in terms of interviews' participation.

The age distribution of respondents shows that respondents aged over 35 accounted for 86.37% of the total sample. This likely reflects the local situation that the middle-aged and elderly tend to work in their villages or stay at homes, while younger people (below 35) tend to work or study outside their villages. The education levels of the respondents show a high percentage of low education levels, with 50.47% of them having completed only secondary school or lower, followed by high school (47.76%) and higher education (less than 2%).

Cat Ba Island is a tourism destination, and thus more than half of the sample (61%) was made of casual workers, hired workers, traders, and business owners (e.g., hotel and restaurant owners). The remainders were farmers, housewives, government officers, retirees, and others. Most of respondents (97.71%) were permanent residents (Table 3). The average household size in the sample was 3.99 persons, which is equivalent to the normal family size (3.95) for the Cat Hai District where Cat Ba Island is located (Cat Hai Division of Statistics (CHDS), 2019). Over 75% of respondents had a monthly household income of less than or equal to US$500, followed by a 17.07% being in the range between US$501 to US$1000, and 6.14% receiving more than US$1000 (Table 3). These higher monthly income households were mainly from business owners, including restaurant and/or hotel owners. About 13.5% of households had monthly income of less than US$150 and these households are likely to be poor, with incomes lower than the poverty level set by the UN poverty indicator (US$1.9 per capita per day) (WorldBank, 2017).

4.2. Willingness to pay estimates

Analysis shows that most respondents (83.5%) are willing to contribute to the construction of reservoirs while only 26.2% of respondents are supporting the higher water prices on Cat Ba Island (Table 3). In addition, 19.9% of respondents are willing to contribute for both construction of reservoirs and higher water price on the island. The result of Chi-square test for independence also confirmed that there is a significant difference ($\chi^2 = 32.5$, df = 1, $p \leq = 0.0005$) in respondents' perceptions between WTP for building reservoirs and for higher water prices.

The mean WTP was estimated at US$4.36 for building reservoirs and at US$0.08 for increasing water price. Most of respondents offered a bid at US$2.15 for building reservoirs (41% of WTP's respondents) and at US$0.04 for increasing water price (10% of WTP's respondents).

Table 2
Socio-demographic characteristics of the respondents and WTP (n = 961).

	Category	Respondents	Percentage
Gender	Male	426	44.33
	Female	535	55.67
Age (years old)	18–26	9	0.94
	26–36	122	12.70
	36–46	227	23.62
	46–56	274	28.51
	>56	329	34.24
Education	Primary school	89	9.26
	Secondary school	396	41.21
	High school	459	47.76
	College	4	0.42
	University & Postgraduate	13	1.35
Occupation	Aquacultures	31	3.23
	Farmers	131	13.63
	Free workers	220	22.89
	Government officers	71	7.39
	Hired workers	46	4.79
	Tourism related jobs	320	33.30
	Housewives	81	8.43
	Retired	61	6.35
Residence	Permanent	939	97.71
	Temporary	22	2.29
Household size (person)	1 to 2	148	15.40
	3 to 4	534	55.57
	5 to 6	240	24.97
	7 to 8	39	4.06
Residence place	Cat Ba Town	599	62.33
	Communes	362	37.67
Income (USD)	0 to 500	738	76.80
	501 to 1000	164	17.07
	1001 to 2500	39	4.06
	> 2500	20	2.08

*US$1 is equivalent to VN$23,273 on 30th May 2019.

Table 3
Distribution of respondents by bid amount.

Bid level (VND)		Number of respondents	Yes WTP	Percentage (%)
WTP Reservoirs	10,000	961	49	5.10
	20,000	961	140	14.57
	50,000	961	390	40.58
	150,000	961	125	13.01
	300,000	961	95	9.89
Bid level (VND)		Number of respondents	Yes WTP	Percentage (%)
WTP Water price	500	961	55	5.72
	1000	961	98	10.20
	2000	961	72	7.49
	4000	961	24	2.50
	6000	961	3	0.31

*US$1 is equivalent to VN$23,273 on 30th May 2019.

Respondents' offers decrease when the bids increase for both building reservoirs and increasing water prices (Table 3).

4.3. Willingness to pay reasons

Analysis of respondents' reasons of WTP for building reservoirs indicates that 83.5% of respondents are willing to support the construction of reservoirs. Among them, a large proportion of respondents (41.88%) are more vocal for this option and willing to support if the authority calls for contributions. The second largest group of respondents (35.3%) supports this option because they believe that this is the most effective solution to increase water supply sources, especially in the dry seasons. A small group of residents (12.4%) also argues that building reservoirs should see both the government and residents working together for social benefits.

However, about 16.5% of respondents are not willing to pay and most of these respondents (30.5%) thought the government should raise funds from other sources. About 14.91% of respondents in this group do not see the need to build reservoirs, and 13.5% of respondents also suggest checking the feasibility of the project first. Some respondents (11.8%) believe that private investors should fund themselves. Importantly, 7.45% of respondents could not afford the payment. Finally, 18% of these respondents did not provide an answer.

In contrast to building reservoirs, only 26.2% of respondents are willing to support for increasing water price, and most of them (33.3%) think that increasing water price will increase the residents' responsibility. The second largest proportion (23.13%) states that increasing water price will improve water usage efficiency. About 14.29% of respondents think that increasing water prices will improve water services, and 13.67% of respondents state that they will follow the market rule. The

Table 4
Relationships between respondents' WTP for building reservoirs and respondent' socio-demographics and perceptions.

Name	Akaike weight	Rank of importance	Estimate	Variance	Confidence interval (95%)
Tourism development	1	1	−0.888	0.156	−1.19 to −0.58
Residence	0.94	2	1.339	0.593	0.18 to 2.50
Age	0.85	3	−0.016	0.010	−0.04 to 0.00
Water use sources	0.62	4	0.209	0.227	−0.24 to 0.65
Occupation	0.53	5	0.038	0.051	−0.06 to 0.14
Gender	0.51	6	−0.114	0.177	−0.46 to 0.23
Monthly water use	0.43	7	−0.000	0.001	0.00 to 0.00
Education	0.35	8	0.044	0.109	−0.17 to 0.26
Household size	0.33	9	−0.017	0.045	−0.10 to 0.07
Residence place	0.29	10	−0.027	0.121	−0.26 to 0.21
Climate change impact	0.28	11	0.017	0.092	−0.16 to 0.20
Monthly income	0.28	12	0.000	0.000	0.00 to 0.00

Table 5
Relationships between respondent' WTP for increasing water price and respondent's socio-demographics and perceptions.

Name	Akaike weight	Rank of importance	Estimate	Variance	Confidence interval (95%)
Climate change impact	1	1	−0.825	0.1703	−1.16 to −0.4
Monthly income	1	2	0.000	0.0000	0.00 to 0.00
Residence place	1	3	−1.107	0.1790	−1.46 to −0.76
Age	0.77	4	−0.011	0.0085	−0.03 to 0.01
Water use sources	0.64	5	0.205	0.2103	−0.21 to 0.62
Tourism development	0.58	6	0.159	0.1871	−0.21 to 0.53
Monthly water use	0.50	7	0.001	0.0009	0.00 to 0.00
Residence	0.31	8	−0.114	0.3458	−0.79 to 0.56
Occupation	0.31	9	0.008	0.0257	−0.04 to 0.06
Gender	0.28	10	−0.015	0.0895	−0.19 to 0.16
Education	0.28	11	−0.001	0.0709	−0.14 to 0.14
Household size	0.27	12	−0.002	0.0316	−0.06 to 0.06

rest of respondents also suggest setting up different prices depending on water usage and educating tourists to save water.

However, 73.8% of respondents are not willing to pay for increasing water price. A large percentage of these respondents (38.93%) claimed that increasing water price will impact their living costs, affect their businesses, and reduce their incomes. Other respondents (16.64%) were happy with current water prices, and 10.89% of respondents in this group state that increasing water price would not be suitable method to save water. About 8.24% of respondents state that they could not be affordable to pay more for increasing water price. Some respondents (6.07%) suggest that business only should pay the higher prices as they use a large proportion of water.

4.4. Relationships among variables

The Spearman's rank-correlation tests show that all variables have strong relationships with each other (Appendix 1), and these variables are classified as collinear variables. Several variables have multi-dimensional relationships with other variables (Appendix 1). For example, age is strongly correlated with the largest number of variables (11 other variables). In addition, four variables (e.g., residence place, education, monthly income, and monthly water usage) have strong correlations with nine variables. Conversely, climate change and household size have the lowest number of strong relationships with other variables (four variables). WTP for building reservoirs has strong relationships with six other variables, such as age, education, residence, water use sources, climate change impacts and tourism development (Appendix 1). WTP for increasing water price also has strong relationships with seven variables, including: residence place, gender, age, monthly income, water use sources, monthly water uses and climate change impact (Appendix 1).

A logistic regression model with model averaging suggests that only six out of 12 explanatory variables have strong relationships with respondents' WTP for building reservoirs (Akaike weight of >0.5), including: tourism development, residence, age, water use sources, occupation, and gender (Table 4).

The logistic regression model with model averaging also indicates that seven of 12 explanatory variables have strong relationships with WTP for increasing water price (Akaike weight of >0.5), including: climate change impact, monthly household income, residence place, age, water use sources, tourism development and monthly water use (Table 5).

4.5. Determinants of respondents' WTP for building reservoirs and higher water prices

The strongest correlated variables with WTP for building reservoirs or increasing water price (Akaike weight of >0.5) in Table 4 and 5 were used to build two models: WTP for building reservoirs (Fig. 7) and WTP for increasing water price (Fig. 8). The models indicate that the prior probability of Yes (WTP) based on the provided evidence, are 83.5% of respondents willing to pay for building reservoirs (Fig. 7), and 26.2% of respondents willing to pay for increasing water price (Fig. 8).

These models can be used to calculate the probability of interest by setting input conditions based on hypothesised scenario. Specifically, the probability distribution of the target WTP nodes can be updated through the network once new evidence for each category is entered. For example, the impacts of different ages on the WTP can be obtained by setting the age range of interest to 100% in the Age input node (Figs. 7 and 8). The age range between 36 and 46 is the one providing the largest probability of WTP for building reservoirs; however, the age range between 26 and 36 is the one providing the largest probability of WTP for increasing water prices (Fig. 9).

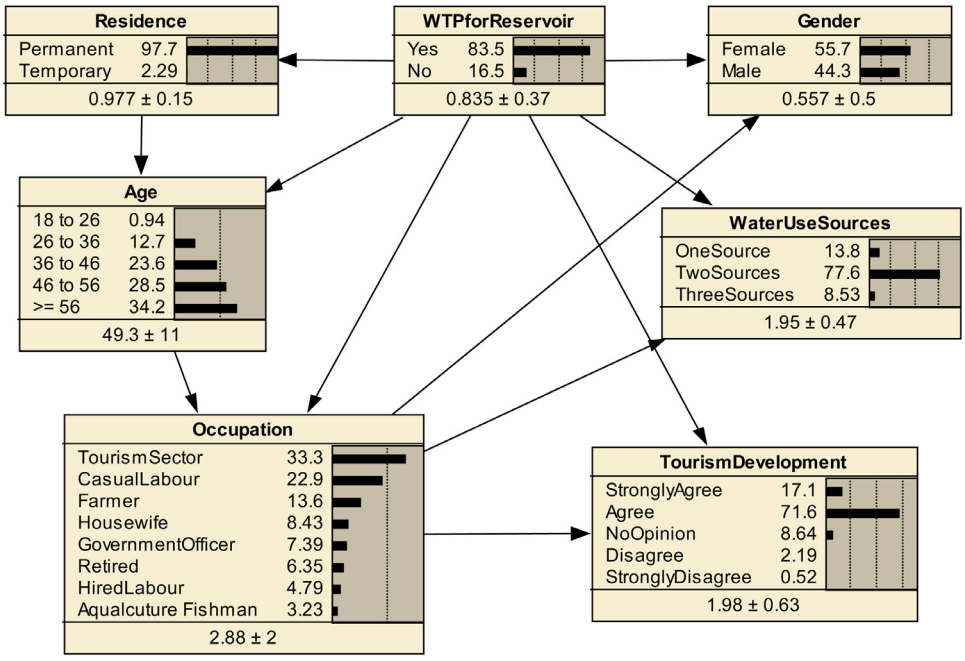

Fig. 7. The Bayesian Network model for identifying determinants of building reservoirs.

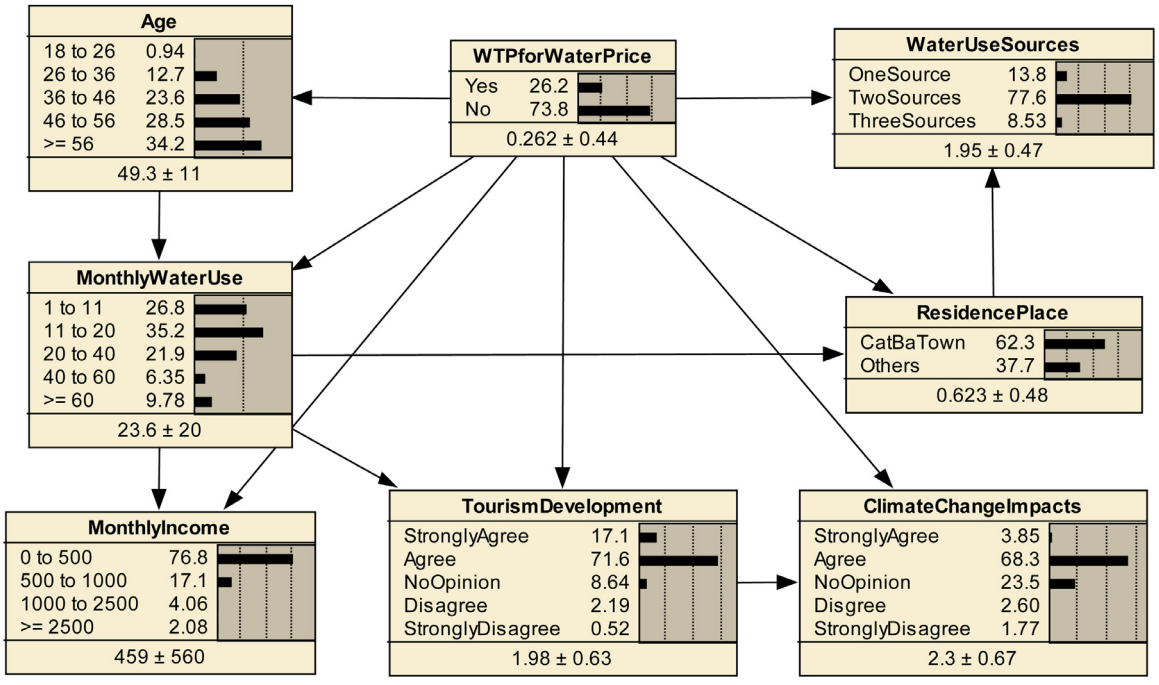

Fig. 8. The Bayesian Network for identifying determinants of increasing water price.

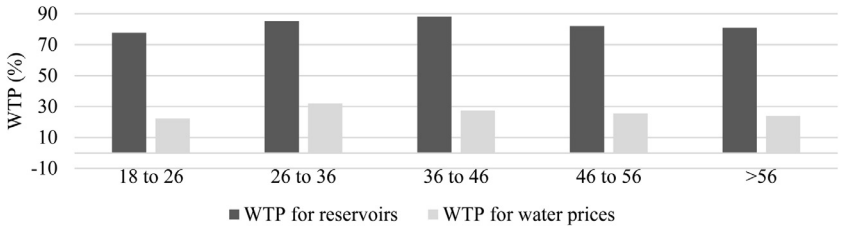

Fig. 9. Impacts of different ages on respondents' WTP for building reservoirs and increasing water prices.

Table 6
Confusion matrix for the two developed BN.

a) WTP for Building reservoirs					
	Predicted values			Sensitivity	0.96
		Yes	No	Specificity	0.65
Actual values	Yes	770	29	Accuracy	0.91
	No	57	105	Precision	0.93
b) WTP for higher water prices					
	Predicted values			Sensitivity	0.64
		Yes	No	Specificity	0.93
Actual values	Yes	215	66	Accuracy	0.89
	No	38	642	Precision	0.85

4.6. Model evaluation result

The high cross-validation accuracies of the model predictions for building reservoirs (Table 6a) and increasing water price (Table 6b) indicate that the models have good classification capacity. However, the sensitivity (true positive rate) and specificity (true negative rate) were not consistently as high as the overall accuracy, indicating the models have slightly overall bias in classification (Table 6). Specifically, only 65% of No WTP is accurately classified by the model for building reservoirs, and only 64% of Yes WTP is accurately classified by the model for higher water prices.

Sensitivity analysis on the model highlights tourism development as the most influential factor affecting the respondents' WTP for building reservoirs, followed by occupation, residence, age, water use sources, with gender being the least influential factor (Table 7a). Climate change impact is the most influential factor for respondents' WTP for higher water prices, followed by monthly income, water use sources, residence place, tourism development, monthly water use, with age being the least influential factor (Table 7b).

5. Discussion and conclusions

Cat Ba Island is a famous destination for both national and international tourists. However, water resources management is being under considerable threats from climate change and tourism development. To the best of our knowledge, this is the first study that applied both logistic regression models with model averaging and Bayesian networks to examine multi-dimensional stakeholders' perceptions and identify determinants affecting the respondents' WTP for building reservoirs and/or increasing water price to cope with increased tourism influxes and climate change.

This modeling approach provides decision-makers with a transparent, probabilistic, and graphical tool for exploring the impacts of different and interacting drivers (e.g., occupations, monthly income) on respondents' WTP. For example, analysing the impact of different occupations on WTP indicates that the government officers have the largest impact on the WTP for building reservoirs with 94.4% of WTP, and most of these officers are permanent residents (99.8%), use two water resources (84.4%), and agree (80.3%) that the development of tourism strongly affect water resources management. In addition, the impact of household monthly income on the WTP for increasing water price is different among monthly income ranges. The respondents' willingness to support the option of higher water prices increases gradually when their incomes increase. For example, the respondents with monthly income more than US$2,500 have the highest WTP (90%) for increasing water price. This could reflect that these much higher income groups are business owners, including restaurant and/or hotel owners, accounting for 85% of respondents in this income range. These groups usually consume large amounts of waters, and they face water shortage in the peak tourism seasons, and thus they are willing to pay for higher water prices. All these findings are consistent with previous studies (Keough and Vásquez, 2020; Peng et al., 2018; Pham et al., 2018). Specifically, Pham et al. (2018) and Peng et al. (2018) indicated that occupations have strong influence on the respondents' WTP for mangrove restoration in Cat Ba Island, Vietnam, and water resource reservations in Beijing, China, respectively. In addition, Keough and Vásquez (2020) stated that more educated respondents are willing to pay more for watershed protection than less educated individuals

In this study, a multi-dimensional stakeholder involvement (e.g., decision makers, water managers, water users, tourism providers) from Hai Phong and Cat Ba Island has provided a comprehensive range of critical and practical perspectives on the nexus of scarce water resources management, tourism development and climate change. Especially, respondents' perceptions and modeling results reveal that a high proportion of respondents agree that climate change and tourism development are crucial factors causing water shortage on Cat Ba Island. This reflects the actual conditions on the island as altered precipitation regimes, sea level rise and temperature increase over time have caused high level of salinity intrusion in seven out of nine drilled wells, low water levels in family dug wells and water tanks, thereby causing high water shortage over past summers, especially in the peak tourism seasons from April to August in the island (Cat Hai Water Supply Plant (CHWSP), 2019). As a result, Cat Hai Water Supply Plant used boats to transport freshwater from the mainland to sufficiently supply for the island residents, especially in the Cat Ba Town which is the central tourism destination of the island (Cat Hai Water Supply Plant (CHWSP), 2019). The residents have experienced the severe water shortage and thus they believed that the water shortage in the island is strongly driven by climate change and tourism development. These findings are consistent with a study conducted by Gebretsadik and Romstad (2020) which indicated that climate change has significant and positive effect on farmer's willingness to pay for improved irrigation water supply because climate change (e.g., severity drought) has affected and reduced their crops' productivity. In addition, March et al. (2014) indicated that climate change and tourism development are perceived as important factors negatively affecting the management of water resource systems. It is also true that tourism is one of the main driving forces for economic growth for many destinations in the world; however, tourism development can have serious negative impacts on

Table 7
Results of sensitivity analysis (variance reduction analysis): input variables and their effects on posterior outputs.

(a) Building reservoirs		(b) Increasing water price	
Variable	Variance reduction (%)	Variable	Variance reduction (%)
Tourism development	5.52	Climate change impact	11.50
Occupation	1.13	Monthly income	6.80
Residence	1.01	Water use sources	3.14
Age	0.63	Residence place	3.10
Water use sources	0.38	Tourism development	0.78
Gender	0.18	Monthly water use	0.69
		Age	0.33

the environment, especially the water resources (Gössling et al., 2006; Van Der Veeken et al., 2016). The tourism-related water demand coupled with climate change (e.g., sea level rise and precipitation decline) can generate serious problems of overexploitation or depletion at most coastal and small island destinations where water supply sources are limited and scarce (Deyà Tortella and Tirado, 2011; Phan et al., 2018).

One of the most important findings is that most of respondents are willing to support a long-term solution - building reservoirs, while only a small proportion of respondents seem to choose a short-term option - willing to cope with the higher water prices. This preference can be justified by the fact that building reservoirs is an effective and sustainable solution to store water in rainy seasons and supply water sufficiently across all tourism seasons. In contrast, respondents stated that increasing water price would not be a suitable method to save water due to a high-water demand from tourism activities on the island. These findings are consistent with Young (2005) who indicated that increasing water price is generally not considered an effective tool to save water in the long-term as water users will adapt to the higher prices. When discussing the role of prices in managing water scarcity, Zetland (2021) also indicated that scarcity-bolstered prices might not support for the water demand management in the long run, but they can encourage to find alternative water supply sources, such as digging more wells and building more reservoirs or desalination plants. It is also noticeable that the socio-demographic characteristics of respondents are different in their support on these two solutions. For example, respondents who have an income less than US$500 have more support for a long-term solution rather than a short-term option, possibly reflecting that these households have low incomes and increasing water price would affect their living cost. In addition, respondents who use three water sources have more support for both solutions than that use less water sources. This is because these households consume large proportion of water, and they use all water sources available on the island, and thus they are willing to support for both these solutions to satisfy their daily water demands.

Another important finding is that the current study is one of first applying multi-stakeholders' perceptions to construct DAGs and populate CPTs for BNs, to identify the influential factors on respondents' WTP for better water resources management. The knowledge base for the construction of BNs is widely recognised as an important driver of model outcomes and performance (Marcot, 2012). Expert opinion and/or model simulation and/or empirical data can be used to construct DAGs and populate CPTs for BNs (Jensen and Nielsen, 2007). However, expert knowledge has been mostly used to construct DAGs and populate CPTs for BNs due to the limited available data in water resource modeling (Phan et al., 2016). More importantly, most of such participatory BNs were not validated or just validated by experts [e.g. Giordano et al. 2013] to increase the confidence in decision-making process. In this study, respondents' perspectives were used to construct DAGs, populate CPTs, and validate the BNs. Specifically, logistic regression models with model averaging were used to exclude some variables that were of less influence on respondents' WTP and avoid the multicollinearity problems arising among independent variables. As a result, simple BNs were developed by including just six highly correlated influential variables for building reservoirs, and seven highly correlated influential variables for increasing water prices. These simple network models have more tractable CPT dimensionality, thereby increasing the ability of interpretation and parameterization of the models (Phan et al., 2019b). Therefore, the prediction accuracy of these models was quite high, i.e., 91% and 89% for building reservoirs and increasing water price, respectively. These BNs can be reliably used to understand importance of influential factors on respondents' WTP, assisting decision-makers in quantifying uncertainty and determining perceptions on the nexus between water resources management, tourism development and climate change.

Despite clear benefits, the current study has several limitations. First, the study has a potential bias in the interview process, possibly affecting the quality of the data collection. Specifically, climate change, tourism development and scarce water resources management are complex interactions, thereby causing difficulty for respondents who have low education levels to fully understand and answer the questions. In order to limit this bias, we have carefully designed the questionnaire and conducted interview process to avoid the potential interview bias and reflect the perspectives and opinions of the respondents on the management of scarce water resources in the island. Especially, the questionnaire was carefully co-designed with experienced survey experts as simple and clear as possible to make sure that all questions are easily understood by all respondents. In addition, it was tested by randomly interviewing five households in a pilot study for its usability before interviewing the planned respondents in the whole island. Second, logistic regression models with model averaging and Bayesian networks are applied to identify determinants affecting the respondents' WTP for scarce water resources management under climate change and tourism development. This modeling approach could have some unclear factor correlations which are subjective and depends on the respondents and interviewed samples. These limitations should be improved in the future work.

Despite this potential limitation, the current study is the first attempt to investigate and explore the perceptions and experiences of multi-dimensional stakeholders on the tourism-water resources-climate change nexus. The perceptions of tourism providers and particularly their past experiences and expectations about water resources management under climate change – represent a considerable gap in the literature because previous research has mainly focused on the perceptions of tourists (Gössling et al., 2006; Andereck, 2009). Therefore, the findings from this study can contribute to formulating policies and decision-making support related to tourism development, climate change and water resources management not only in Cat Ba Island but also in other coastal and small island tourist destinations. If implemented correctly, these management policies have the potential to simultaneously strengthen the tourism industry and protect the water resources under climate change.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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