sustainability

MDPI

Supplementary

S1. Questionnaire on the value of ecosystem services in Chinan Catchment, Hualien (experts).

Hello:

This is a questionnaire administered by the research team of professor Yu-pin Lin from the Department of Bioenvironmental Systems Engineering, National Taiwan University. The research purpose is to understand how much you agree with the value of ecosystem services in the study area and the amount of money you are willing to pay annually to maintain ecosystem service functions in response to climate change (this purely investigational research will never involve actual payment). Your answers will be used only for academic research, and they will never be released for other uses. Please feel free to provide your opinions; your contribution to this research is highly appreciated.

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Background

- Challenge: Affected by climate change, the functions of hydrological ecosystem services in the study area will decrease in the future.
- Strategy: Propose a water resource adaptation plan in response to climate change.
- Research question: How much are we willing to pay to maintain the functions of hydrological ecosystem services?

1. Summary of research results

In this study, the Chinan Catchment Area was the research site (this is estimated to be the most water-scarce area in Hualien because of climate change). The Integrated Valuation of Ecosystem Services and Tradeoffs model (InVEST model) was used to quantify various hydrological ecosystem services by comparing current and future climate change scenarios and analyzing changes in hydrological ecosystem services in the study area. The four indicators included in the assessment were (1) water yield, (2) sediment export, (3) nitrogen nutrient export, and (4) phosphorus nutrient export. The climate change scenario setting is was based on the future climate scenario outlined in the Fifth Assessment Report (AR5) published by the United Nations Intergovernmental Panel on Climate Change in 2012. The selected scenarios were simulated using each of the five global circulation models (i.e., CCSM4, CESM1-CAM5, GISS-E2-R, HadGEM2-AO, and MIROC5) under the 2.6 and 8.5 representative concentration paths to simulate changes in the functions of hydrological ecosystem services.

The results indicated that:

(1) According to a comparison of the simulation results of the next 20 years with the baseline period which refers to 1986-2005, climate change will cause the average monthly water yield to increase by up to 45% or to decrease by up to 88% from the base period, indicating a wide range of fluctuation.

(2) The annual average amount of water yield will increase, and monthly water yield will increase during the wet season and decrease during the dry season. The increased annual water yield will be concentrated in the wet season.

(3) The changes in sediment export will be similar to that of water yield; the annual average export will increase, and these increases will be concentrated in June–October. The sediment export results calculated by multiple GCM models indicated an increase of more than 50% relative to the base period. Large soil losses will negatively affect hydrological service functions. Changes

in nutrient export (of nitrogen and phosphorus) will be small, but their monthly averages will fluctuate more.

2. Definition

Ecosystem services refer to the benefits directly or indirectly provided to humans by the earth's natural systems (Daily, 1997, MA, 2005). These benefits can be classified into three aspects: provision, regulation, and culture, all of which concern human and environmental sustainability. Hydrological ecosystem services are a subset of ecosystem services and refer to water-related services provided by ecosystems to humans. Hydrological ecosystem services can be divided into five major categories: water intake, river water supply, mitigation of water hazards, water-related cultural services, and water-related support services (Brauman et al., 2007). These services directly and indirectly affect the supply and demand of water resources and are closely related to human survival and development.

Basic information of interviewed experts

1. What is your gender?

   □ Male □ Female

2. What is your age?

   □ <29 years □ 30–39 years □ 40–49 years □ 50–59 years □ 60–69 years □ ≥70 years

3. How many people are in your household?

   □ 1 person □ 2 people □ 3 people □ 4 people □ ≥5 people

4. What is your monthly income?

   □ Prefer not to disclose □ <NT$50,000 □ NT$50,000–NT$100,000
   □ NT$100,000–NT$150,000 □ NT$150,000–NT$200,000 □ >NT$200,000

5. What is your area of residence?

   □ Northern □ Central □ Southern □ Eastern □ Outlying islands □ Other

6. What area is your hometown in?

   □ Northern □ Central □ Southern □ Eastern □ Outlying islands □ Other

Relevance between experts and study area or topic

7. Overall, how interested are you in the development of the study area over the next 10 to 15 years?

   □ Very interested □ Quite interested □ A little interested □ Not interested at all

8. How well do you understand what ecosystem services are?

   □ Very well □ Well □ Not well □ A little □ Not at all

9. How well do you understand the definition of hydrological ecosystem services?

   □ Very well □ Well □ Not well □ A little □ Not at all

10. To what extent do you agree that the function of ecosystem services is important?

    □ Strongly agree □ Agree □ No opinion □ Disagree □ Strongly disagree

11. Have you participated in research related to ecosystem services?

    □ Yes, often as an investigator □ Yes, with experience as an investigator
    □ Yes, with experience as an assistant □ No, but I have heard of this research □No, I have never heard of this research

12. Have you participated in research related to water resources in eastern Taiwan?

□Yes, often as an investigator □Yes, with experience as an investigator □ Yes, with experience as an assistant □ No, but I have heard of this research □No, I have never heard of this research

13. The hydrological ecosystem services of the Hualien Chinan Catchment Area include water yield, sediment export, and nutrient (nitrogen, phosphorus) export. Please score the following hydrological ecosystem service items by importance on the basis of your perceptions and experience.

hydrological ecosystem services	**Specific function**	**Importance score** **Not important----------Very important**									
Water yield	Water supply	□1	□2	□3	□4	□5	□6	□7	□8	□9	□10
Sediment export	Maintain soil strength	□1	□2	□3	□4	□5	□6	□7	□8	□9	□10
Nutrient (nitrogen and phosphorus) export	Maintain water quality	□1	□2	□3	□4	□5	□6	□7	□8	□9	□10

Willingness to pay

14. Are you willing to pay a reasonable fee to maintain the ecosystem service function of the research area? (This is a hypothetical question, and you will not incur any actual expenses. We ask this question only to understand the value of hydrological ecosystem services in the research area.)

□ Very willing □ Willing □ Neutral □ Unwilling □ Very unwilling

15. The maintenance of hydrological ecosystem service functions (water yield) in the research area can stabilize water resources in the area. If the ecosystem of the research area can be maintained through water storage and other strategies to maintain abundant fresh water resources (supply function), but a monetary donation is required, what is the maximum amount you are willing to pay per year?

□ NT$0 □ ≤NT$100 □ NT$100–NT$500 □ NT$500–NT$1,000
□ NT$1,000–NT$3,000 □ NT$3,000–NT$5,000 □ >NT$5,000

16. The maintenance of hydrological ecosystem service functions (sediment export) in the research area can stabilize hydrological resources in the area, prevent massive soil loss, and maintain water quality. If the ecosystem of the research area can be maintained through hydraulic engineering and other strategies to protect the soil and maintain water quality (regulatory function), but a monetary donation is required, what is the maximum amount you are willing to pay per year?

□ NT$0 □ ≤NT$100 □ NT$100–NT$500 □ NT$500–NT$1,000
□ NT$1,000–NT$3,000 □ NT$3,000–NT$5,000 □ >NT$5000

17. The maintenance of hydrological ecosystem service functions (nutrient export) in the research area can stabilize water quality. If the ecosystem of the research area is maintained through the use of environmentally friendly chemical pesticides and other strategies to maintain the water quality (regulatory function), but a monetary donation is required, what is the

maximum amount you are willing to pay per year?

□ NT$0 □ ≤NT$100 □ NT$100–NT$500 □ NT$500–NT$1,000
□ NT$1,000–NT$3,000 □ NT$3,000–NT$5,000 □ NT$5,000

18. Why did you answer "very unwilling" or indicate a payment amount of "NT$0" (Please select all that apply)?

□ Maintaining the hydrological system service function of the Chinan Catchment Area has no value to me.

□ The government should bear the cost of maintaining the hydrological system service function of the Chinan Catchment Area.
□ Local resident should bear the cost of maintaining the hydrological system service function of the Chinan Catchment Area.
□ Resource users (such as local agricultural and fishery operators) should bear the cost of maintaining the hydrological system service function of the Chinan Catchment Area.
□ I disagree with using money for this purpose.
□ Other, please specify: _____

Factors to consider when selecting an adaptation program

19. If you were to select a water resource adaptation program in response to climate change (e.g., water supply adaptation program: groundwater extraction, weir construction, addition of water storage and saving facilities, water desalination, or changed irrigation methods), which of the following policy considerations would be your first priority?

□ The function of ecosystem services to satisfy human well-being
□ The economic cost of investment
□ Impact on the ecological environment
□ Social acceptance

20. If you were to select a water resource adaptation program in response to climate change, how would you rank the following considerations from most to least important? (1 is the most important, 2 is the second most important, etc.)

Factor	Ranking
The function of ecosystem services to provide human well-being is satisfied	
The economic cost of investment	
Impact on the ecological environment	
Social acceptance	

Thank you kindly for your help!

Do you have any other comments or suggestions?

S2. Chi-square test results for gender with various independent variables

Table S1. Chi-square test results for gender × agreement with the importance of ecosystem services.

Correlation between gender and agreement with importance.

Agree on importance	Male	Female	Total
Very much agree	19	14	33
Agree	12	1	13
Total	31	15	46

Chi-square tests

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.119a	1	0.024		
Continuity Correctionb	3.661	1	0.056		
Likelihood Ratio	6.048	1	0.014		
Fisher's Exact Test				0.035	0.023
Linear-by-Linear Association	5.008	1	0.025		
N of Valid Cases	46				

Table S2. Chi-square test results for gender × intention to pay.

Correlation between gender and willingness to pay

Willing to pay	Male	Female	Total
1	9	11	20
2	18	3	21
3	4	1	5
Total	31	15	46

Chi-square tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.133a	2	.017
Likelihood Ratio	8.332	2	.016
Linear-by-Linear Association	5.778	1	.016
N of Valid Cases	46		

S3. Chi-square test results for field of expertise with various independent variables

Table S3. Chi-square test results for field of expertise × agreement with the importance of ecosystem services.

Count

		field of expertise			
		1.00	2.00	3.00	Total
Agree on importance	1	7	13	13	33
	2	8	2	3	13
	Total	15	15	16	46

Chi-square tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.013a	2	.030
Likelihood Ratio	6.826	2	.033

		Count			
		field of expertise			
		1.00	2.00	3.00	Total
Agree on importance	1	7	13	13	33
	2	8	2	3	13
Linear-by-Linear Association		4.347	1		.037
N of Valid Cases		46			

a. Three cells (50.0%) have an expected count of less than 5. The minimum expected count is 4.24.

Table S4. Chi-square test results for field of expertise × understanding ecosystem services.

		Count			
		field of expertise			
		1	2	3	Total
understand ES	1	3	10	9	22
	2	10	5	6	21
	Total	13	15	15	43
		Chi-square tests			
		Value	**df**	**Asymp. Sig. (2-sided)**	
Pearson Chi-Square		6.016a	2	.049	
Likelihood Ratio		6.256	2	.044	
Linear-by-Linear Association		3.469	1	.063	
N of Valid Cases		43			

a. None of the cells (0.0%) have an expected count of less than 5. The minimum expected count is 6.35.

S4. ANOVA results for experts' understanding of ecosystem services

Table S5. ANOVA results for experts' understanding of ecosystem services.

		Between Groups	**Within Groups**	**Total**
Understanding ecosystem services	Sum of Squares	3.623	17.333	20.957
	df	2	43	45
	Mean Square	1.812	0.403	-
	F	4.494	-	-
	Sig.	0.017	-	-
Agreement with importance	Sum of Squares	1.968	9.771	11.739
	df	2	43	45
	Mean Square	0.984	0.227	-
	F	4.331	-	-
	Sig.	0.019	-	-
Participation in ecosystem service research	Sum of Squares	11.455	43.871	55.326
	df	2	43	45

		Mean Square	5.728	1.02	-
		F	5.614	-	-
		Sig.	0.007	-	-
	Intention to pay	Sum of Squares	7.222	38.017	45.239
		df	2	43	45
		Mean Square	3.611	0.884	-
		F	4.085	-	-
		Sig.	0.024	-	-

Table S6. Post hoc test results for experts' understanding of ecosystem services.

Dependent variable			Understanding ecosystem services			Agreement with importance			Participation in ecosystem service research			Intention to pay		
	(I) field	(J) field	Mean Difference (I-J)	Std. Error	Sig.	Mean Difference (I-J)	Std. Error	Sig.	Mean Difference (I-J)	Std. Error	Sig.	Mean Difference (I-J)	Std. Error	Sig.
Tukey HSD	1	2	0.667*	0.232	0.017	0.467*	0.174	0.027	1.067*	0.369	0.016	0.6	0.343	0.2
		3	0.5	0.228	0.084	0.413	0.171	0.052	1.063*	0.363	0.015	0.958*	0.338	0.019
	2	1	−0.667*	0.232	0.017	−0.467*	0.174	0.027	−1.067*	0.369	0.016	−0.6	0.343	0.2
		3	−0.167	0.228	0.747	−0.054	0.171	0.946	−0.004	0.363	1	0.358	0.338	0.544
	3	1	−0.5	0.228	0.084	−0.413	0.171	0.052	−1.063*	0.363	0.015	−0.958*	0.338	0.019
		2	0.167	0.228	0.747	0.054	0.171	0.946	0.004	0.363	1	−0.358	0.338	0.544
Scheffe	1	2	0.667*	0.232	0.023	0.467*	0.174	0.036	1.067*	0.369	0.022	0.6	0.343	0.229
		3	0.5	0.228	0.103	0.413	0.171	0.066	1.063*	0.363	0.02	0.958*	0.338	0.025
	2	1	−0.667*	0.232	0.023	−0.467*	0.174	0.036	−1.067*	0.369	0.022	−0.6	0.343	0.229
		3	−0.167	0.228	0.767	−0.054	0.171	0.951	−0.004	0.363	1	0.358	0.338	0.574
	3	1	−0.5	0.228	0.103	−0.413	0.171	0.066	−1.063*	0.363	0.02	−0.958*	0.338	0.025
		2	0.167	0.228	0.767	0.054	0.171	0.951	0.004	0.363	1	−0.358	0.338	0.574
Bonferroni	1	2	0.667*	0.232	0.019	0.467*	0.174	0.031	1.067*	0.369	0.018	0.6	0.343	0.263
		3	0.5	0.228	0.102	0.413	0.171	0.061	1.063*	0.363	0.016	0.958*	0.338	0.021
	2	1	−0.667*	0.232	0.019	−0.467*	0.174	0.031	−1.067*	0.369	0.018	−0.6	0.343	0.263
		3	−0.167	0.228	1	−0.054	0.171	1	−0.004	0.363	1	0.358	0.338	0.885

3	1	−0.5	0.228	0.102	−0.413	0.171	0.061	−1.063*	0.363	0.016	−0.958*	0.338	0.021
	2	0.167	0.228	1	0.054	0.171	1	0.004	0.363	1	−0.358	0.338	0.885

* Significant mean difference at the 0.05 level. The field 1, 2 and 3 represents the experts in hydrology, ecology and society, respectively.

S5. Average importance score for experts

Table S7. Average importance score for experts with and without research experience related to ecosystem services and water resources.

		Water yield	Sediment export	Nutrients export
Participated in research projects on ecosystem services	Yes	9.13	8.28	8.41
	No	9.29	7.57	8.43
Participated in research projects on water resources	Yes	9.24	8.59	8.53
	No	9.10	7.93	8.34

S6. Friedman test results

Table 8. Friedman test results for experts' rankings.

Friedman test

Ranks

	Mean Rank
Functional	3.07
Economic	1.78
Environmental	3.33
Social	1.83

Test Statistics [a]

N	46
Chi-Square	54.391
df	3
Asymp. Sig.	0.000

a. Friedman test

Tests of between-subjects effects

Dependent Variable: Ranking

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	90.652[a]	3	30.217	39.033	0.000
Intercept	1150.000	1	1150.000	1485.491	0.000
Rank	90.652	3	30.217	39.033	0.000
Error	139.348	180	0.774		
Total	1380.000	184			
Corrected Total	230.000	183			

a. R Squared = .394 (Adjusted R Squared = .384)

Post hoc tests

(I) rank	(J) rank	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	1.2826*	0.18346	0.000	0.7932	1.7720
	3	−0.2609	0.18346	0.941	−0.7503	0.2286
	4	1.2391*	0.18346	0.000	0.7497	1.7286
2	1	−1.2826*	0.18346	0.000	−1.7720	−0.7932
	3	−1.5435*	0.18346	0.000	−2.0329	−1.0540
	4	−0.0435	0.18346	1.000	−0.5329	0.4460
3	1	0.2609	0.18346	0.941	−0.2286	0.7503
	2	1.5435*	0.18346	0.000	1.0540	2.0329
	4	1.5000*	0.18346	0.000	1.0106	1.9894
4	1	−1.2391*	0.18346	0.000	−1.7286	−0.7497
	2	0.0435	0.18346	1.000	−0.4460	0.5329
	3	−1.5000*	0.18346	0.000	−1.9894	−1.0106

Based on observed means. The error term is mean square (error) = 0.774.

* Significant mean difference at the 0.05 level.

S7. The reasons of unwillingness to pay

Table S9. Respondents' explanations for their unwillingness to pay.

Selections	No. of persons
Maintaining the hydrological system service function of the Chinan Catchment Area has no value to me.	1
The government should bear the cost of maintaining the hydrological system service function of the Chinan Catchment Area.	7
Local residents should bear the cost of maintaining the hydrological system service function of the Chinan Catchment.	4
Resource users (such as local agricultural and fishery operators) should bear the cost of maintaining the hydrological system service function of the Chinan Catchment.	11
I disagree with using money for this purpose.	3
Other. The use of engineering methods should be reduced as an adaptation plan.	1

S8. Research architecture diagram

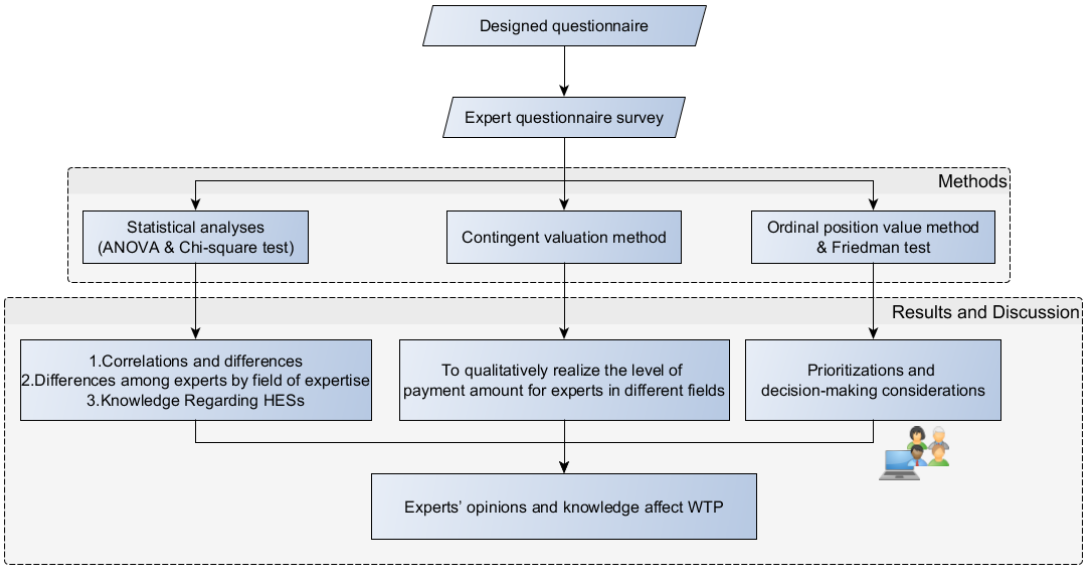

Figure S1. Flow chart.

Reference

1. Brauman, K.A.; Daily, G.C.; Duarte, T.K.; Mooney, H.A. The nature and value of ecosystem services: An overview highlighting hydrologic services. Annual Review of Environment and Resources. **2007**, *32*, 67–98.
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