Valuing Water Storage Systems in Water Scarce Environments:

A Choice Experiment in Nepal's Koshi River Basin

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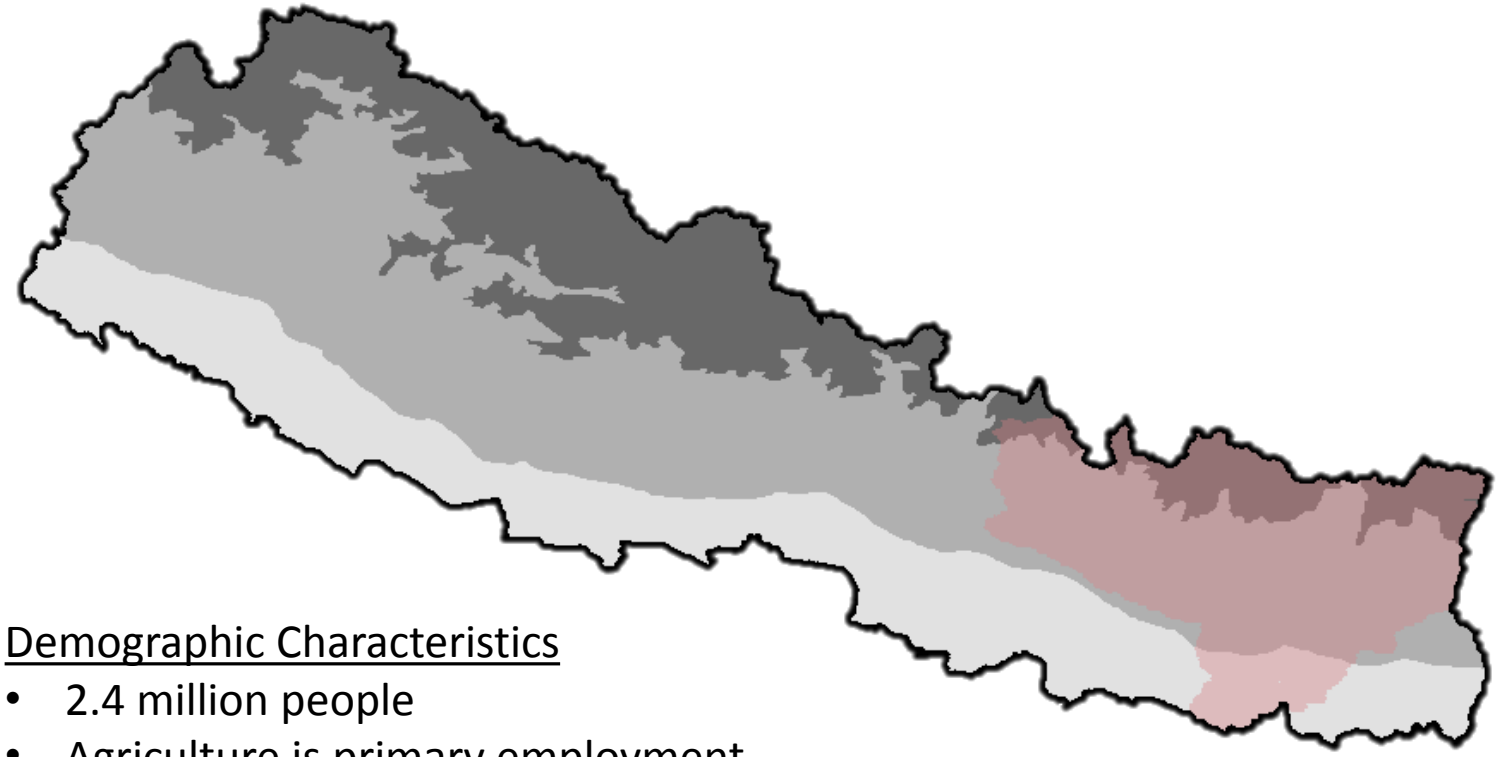
Hill Region of the Koshi Basin



Demographic Characteristics

- 2.4 million people
- Agriculture is primary employment (Rice, Maize, Millet, Potatoes)
- 78% have access to piped water
- 71% have access to toilet facilities

Climate

- 950-4000mm in annual rainfall
- 80% falls between Jun. and Sept.

Water Storage Systems

- Collect and store water from rainfall, springs, or streams for domestic and irrigation purposes
- Storage methods: ponds, reservoirs, tanks, multi-use systems
- The Department of Irrigation
  - Water tanks
  - Concrete ponds (100,000-150,000 liters)
- NGOs and INGOs
  - Water tanks
  - Plastic-lined ponds (20,000 liters)

Current and Planned Storage in the Koshi Basin, Working Paper

Survey Objectives

- Develop a survey instrument to elicit household preferences for water storage systems (WSS)
  - Incorporate individual status quo
  - Applicable to a wide range of climates, cropping patterns, and livelihoods
- Use econometric methods to estimate household preferences for WSS
  - Estimate marginal implicit prices and compensating variation
  - Identify cost-effective technologies
  - Investigate possible preference heterogeneity
  - Conditional on preference heterogeneity, evaluate distribution of welfare effects across sub-groups

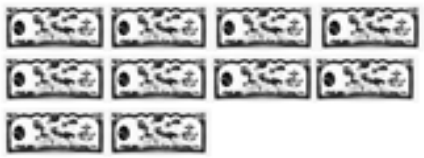
Previous Research

- Drinking Water
  - Whittington (1990), Casey et al. (2006), Hope (2006), Abou-Ali and Carlson (2004; Working Paper)
- Irrigation Water
  - Chandrasekaran et al. (2009), Aheeyar (2006), Barton and Baron (2010), Barton and Bergland (2010)

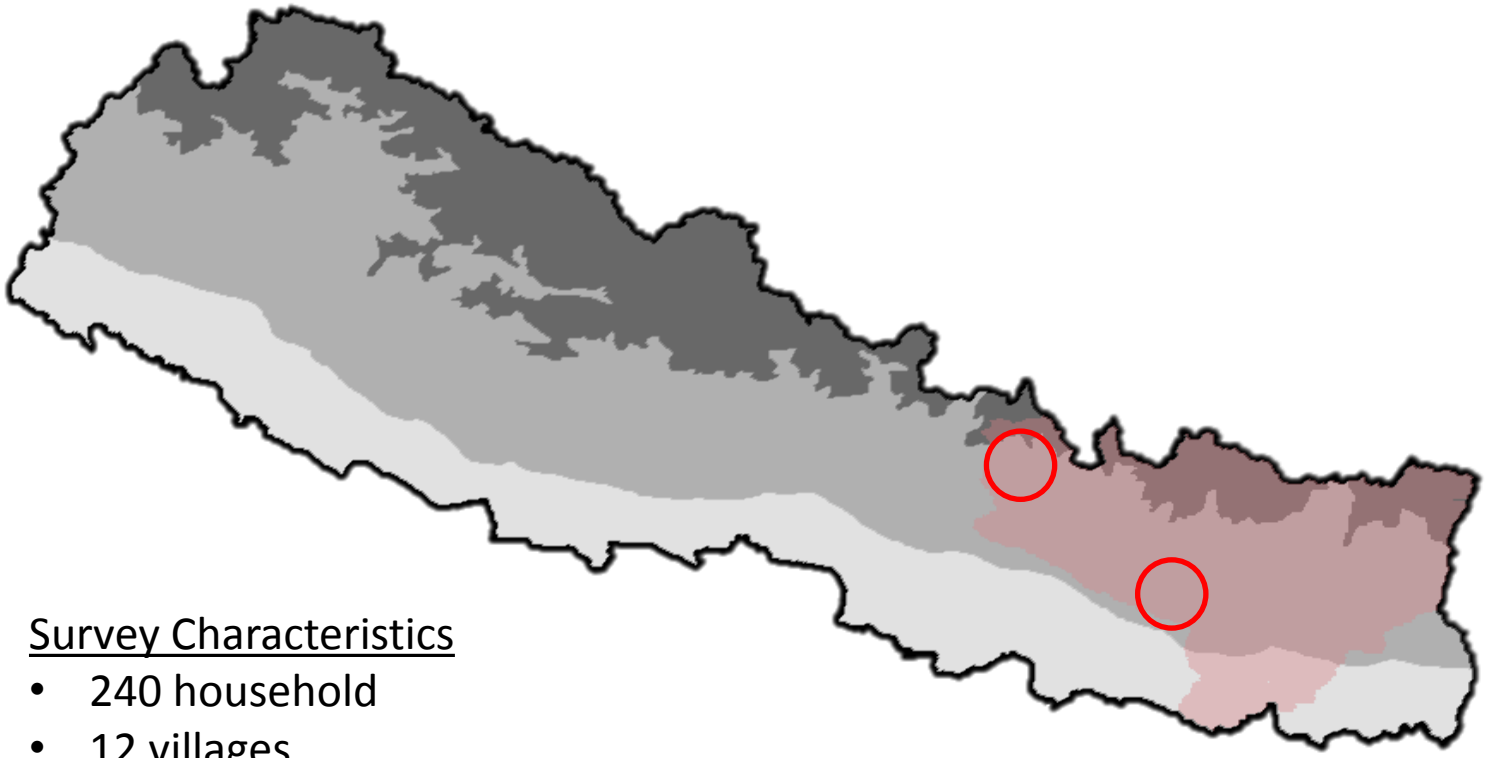
Choice Experiment: Attributes

Attribute	Description	Levels
High Yield	Years per decade with low water stress and high productivity.	5 , 7 and 9
Low Yield	Years per decade with high water stress and low productivity.	0 and 1
Drinking Water	Additional gagri (25 liters) per week of drinking water available in dry season.	0, 1, 2 and 3
Repair Frequency	Years per decade when major repair required.	0, 1, 2 and 5
Labor Contribution	Days of labor household must contribute to construction.	1, 4, 8 and 12
Annual Fee	Annual fee paid by household for operating and maintenance.	200, 800, 1400, 2000 and 2500

Example Choice Experiment

Option 1	Option 2	Option 3
		
		
		
		
		
2000 Rs.	1400 Rs.	0 Rs.
☐	☐	☐

Household Survey



Survey Characteristics

- 240 household
- 12 villages
- Covered 600-1700m, 1700-2000m and 2000-2500m elevation bands.
- Head/Spouse/Adult Member

Descriptive Statistics

	Mean	Standard Deviation
Male	0.60	0.49
Age (Years)	42.82	16.62
Married	0.85	0.36
Bhrahmin/Chhetri/Giri	0.18	0.38
Education	0.52	0.50
Farmer	0.90	0.30
Members (People)	6.02	2.66
Child	0.41	0.49
Wealth (Index)	0.00	1.43
Non-Agricultural Income	0.65	0.48
Improved Water Source	0.77	0.42

Econometric Specification

- Are there classes of people that behave similarly?
  - Class membership unknown.
- Estimate class membership **and** choices jointly.
  - Best fit of class membership and choice responses for class.

Econometric Specification

- Latent Class Model: Utility Function

$$U_{ij|s} = V\left(X_{ij}; \beta_s\right) + \varepsilon_{ij|s} \qquad P_{ij|s} = \frac{\exp[V\left(X_{ij}; \beta_s\right)]}{\sum_{k=1}^{J} \exp[V(X_{ik}; \beta_s)]}$$

- Latent Class Model: Membership Function

$$M_{is} = f(Z_i; \delta_s) + \omega_{is} \qquad P_s = \frac{\exp(Z_i; \delta_s)}{\sum_{s=1}^{C} \exp(Z_i; \delta_s)}$$

Econometric Specification

- Latent Class Model: Unconditional Joint Probability Function

$$P[T(i)] = \sum_{s=1}^{C} \left[\left(\frac{\exp(Z_i; \delta_s)}{\sum_{s=1}^{C} \exp(Z_i; \delta_s)} \right) \times \left(\prod_{t(i)}^{T(i)} \frac{\exp[V(X_{ijt}; \beta_s)]}{\sum_{k=1}^{J} \exp[V(X_{ikt}; \beta_s)]} \right) \right]$$

- Latent Class Model: Log-Likelihood Function

$$L = \sum_{i} \sum_{j \in C} I_j \, lnP[T(i)]$$

Results: Number of Latent Classes

Number of Classes	Number of Parameters	AIC	Consistent AIC	BIC
1	6	2882.54	2909.12	2903.12
2	21	2329.85	2422.87	2401.87
3	36	2195.47	2354.93	2318.93
4	51	2153.21	2379.11	2328.11
5	66	2139.46	2431.80	2365.80
6	81	2110.15	2468.93	2387.93

Results: Utility Function for LCM

	Class 1	Class 2	Class 3
High Yield	0.481*** (0.036)	0.372*** (0.044)	-0.151 (0.151)
Low Yield	-0.944*** (0.125)	-0.034 (0.101)	-0.061 (0.143)
Drinking Water	0.228** (0.106)	1.449*** (0.149)	-0.131 (0.173)
Repair Frequency	0.041 (0.036)	0.121*** (0.038)	-0.101 (0.113)
Labor Contribution	-0.093*** (0.019)	-0.022 (0.023)	-0.014 (0.077)
Annual Fee	-0.02** (0.010)	-0.087*** (0.014)	-0.143*** (0.043)
Choice Sets	1594		
Respondents	228		

Results: Class Characteristics

	Class 1 N=110 (48.3%)	Class 2 N=99 (43.4%)	Class 3 N=19 (8.3%)
Male	0.61	0.58	0.58
Age[ab]	37.43	46.65	53.11
Married	0.85	0.84	0.79
Bhrahmin/Chhetri/Giri[a]	0.25	0.15	0.00
Education[ab]	0.69	0.42	0.11
Farmer[ab]	0.83	0.97	0.89
Members[a]	6.21	6.06	4.32
Child[ab]	0.51	0.29	0.37
Wealth[ab]	0.42	-0.26	-1.16
Sindhupalchok[ab]	0.76	0.49	0.42

Results: Class Characteristics

	Class 1 N=110 (48.3%)	Class 2 N=99 (43.4%)	Class 3 N=19 (8.3%)
Gagri Per Member	3.78	4.08	4.18
Improved Water Source[ab]	0.85	0.68	0.84
Drinking Water Taste[ab]	1.37	1.62	1.74
Drinking Water Cleanliness[ab]	1.38	1.63	1.79
Drinking Water Reliability	1.40	1.53	1.72
Elevation: 500-1700m	0.56	0.54	0.58
Elevation: 1701-2000m	0.35	0.40	0.32
Elevation: 2001-2500m	0.09	0.06	0.11

a=Significant difference between at least one pair of classes at the 5% significance level.

Welfare Measures

Marginal Implicit Price

$$MWTP_n = \frac{MU_P}{MU_A} = -\frac{\beta_A}{\beta_P}$$

- MWTP=Marginal willingness to pay
- MU=Marginal utility
- A=WSS attribute
- P=Cost attribute

Compensating Variation

$$CV = \frac{-(V^1 - V^0)}{\beta_P}$$

- V^0=Indirect utility without WSS
- V^1=Indirect utility with WSS

Marginal Implicit Prices (NRs/Yr.)

	Conditional Logit	Random Parameter Logit	Latent Class Model	
			Class 1	Class 2
High Yield	683.06** (490, 1026)	830.8** (652, 1136)	2,311.08** (1104, 12255)	428.49** (323, 593)
Low Yield	67.6 (-305, 630)	-1,290.19** (-1911, -882)	-4,606.51** (-22986, -2042)	-38.58 (-253, 225)
Drinking Water	1,554.48** (1136, 2334)	1,600.32** (1230, 2163)	1,102.36 (-166, 4647)	1,670.21** (1197, 2464)
Repair Frequency	328.4** (165, 641)	54.18 (-42, 179)	191.3 (-214, 1736)	139.5** (55, 253)

Compensating Variation

Water Storage System Characteristics			
Characteristic	High Yield (Years)	Low Yield (Years)	Drinking Water (Gagri)
Initial Condition	4	2	0
Concrete Lined Pond	8	1	0
Plastic Lined Pond	6	1	0
Multi-Use System	5	1	2

Compensating Variation		
WSS System	Class 1	Class 2
Concrete Lined Pond	14,340	1,749
Plastic Lined Pond	9,530	894
Multi-Use System	9,405	3,798

Appendix: Econometric Specifications

- Conditional Logit

$$U_{ij} = V(X_{ij};\beta) + \varepsilon_{ij} \qquad P_{ij} = \frac{\exp[V(X_{ij};\beta)]}{\sum_{k=1}^{J}\exp[V(X_{ik};\beta)]}$$

- Random Parameter Logit

$$U_{ij} = V(X_{ij};\beta) + \varepsilon_{ij} + \eta_{ij} \qquad P_{ij} = \frac{\exp[V(X_{ij};\beta) + \eta_{ij}]}{\sum_{k=1}^{J}\exp[V(X_{ik};\beta) + \eta_{ij}]}$$

i=Household

Appendix:
Results: Conditional and Mixed Logit

	Conditional Logit		Mixed Logit	
High Yield	0.258***	(0.032)	0.512***	(0.039)
Low Yield	0.025	(0.082)	-0.797***	(0.118)
Drinking Water	0.590***	(0.061)	0.983***	(0.094)
Repair Frequency	0.125***	(0.026)	0.034	(0.031)
Labor Contributions	-0.023*	(0.012)	-0.075***	(0.016)
Annual Fee	-0.038***	(0.007)	-0.062***	(0.009)
Choice Sets	1671		1671	
Respondents	239		239	
BIC	2921.665		2400.419	

Appendix:
Results: Class Membership for LCM

	Class 1	Class 2	Class 3
Age		0.01 (0.014)	0.025 (0.018)
Education		-0.261 (0.448)	-1.998** (0.9)
Farmer		1.455 (1.902)	-0.579 (0.912)
Members		0.107 (0.083)	-0.253* (0.133)
Child		-1.411*** (0.524)	-0.125 (0.635)
Wealth		-0.419** (0.192)	-0.654** (0.273)
Improved Water Source		-1.017* (0.547)	0.413 (0.59)
Sindhupalchok		-1.086*** (0.378)	-1.366*** (0.524)
Constant		-0.314 (2.288)	-0.023 (1.688)