Valuation of Avalanche Protection by Forests

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Valuation of Avalanche Protection

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Background:

- Part of COST-Action E 45:
  ‘European Forest Externalities’ (EUROFOREX)

Aim:

- Development and application of appropriate valuation methods for forest goods and services

Duration:

- 2007-2010

Financing:

- State Secretariat for Education, Research and Innovation

Valuation of Avalanche Protection

Case Study Region:

- Andermatt (ca. 1.300 inhabitants, Kanton Uri)

Co-operation:

- Planning of Landscapes and Urban Systems, ETH Zürich
- Environmental Policy and Economics, ETH Zürich
- WSL Institute for Snow and Avalanche Research SLF, Davos
- LINK-Institute for Market and Social Research, Zürich
- Dept. for Natural Hazards, Canton Bern
- Foresters in case study region

Valuation of Avalanche Protection

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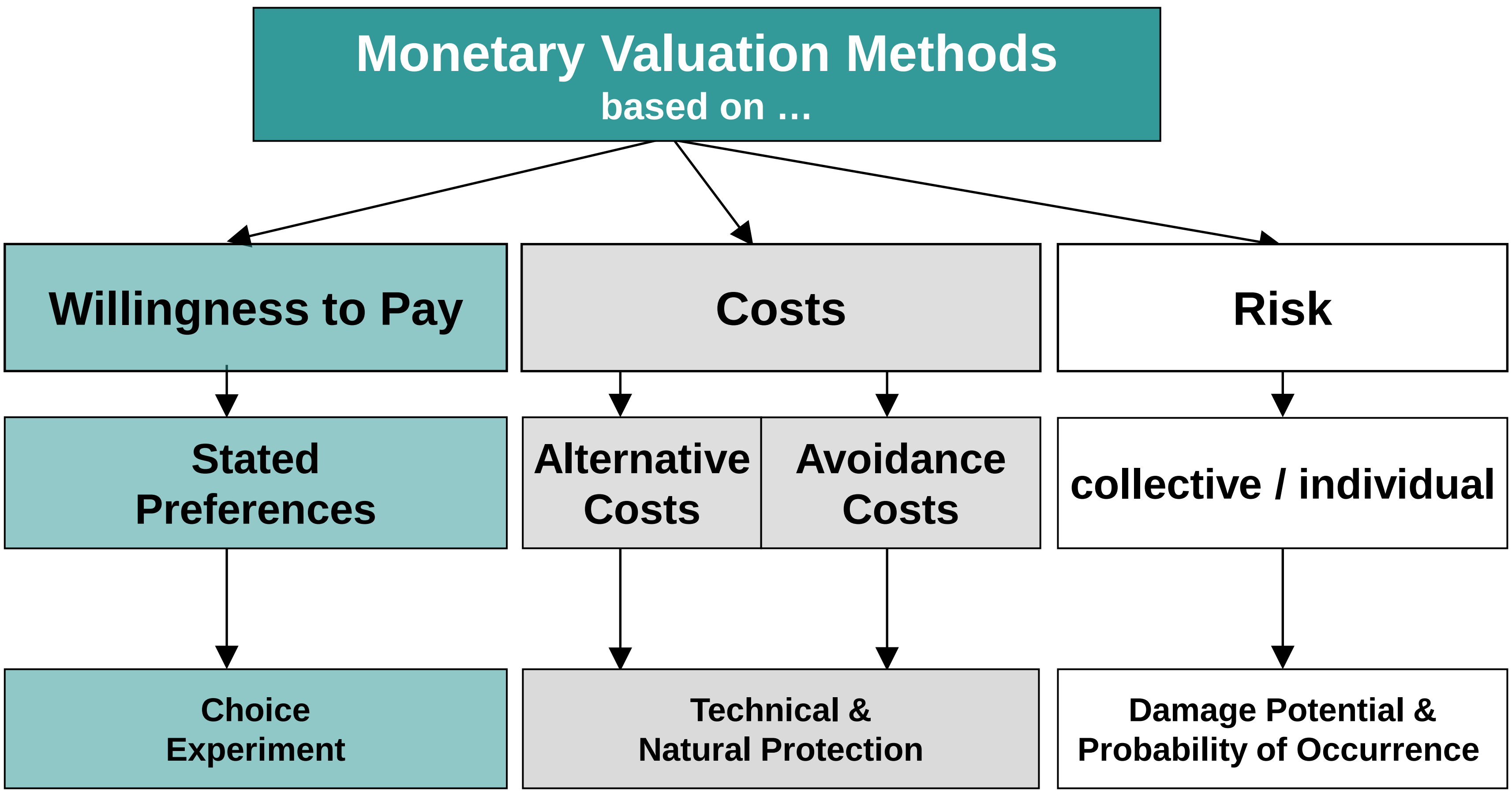


Choice Experiment

- CE is a direct method to determine the value of public goods based on stated preferences

- Origin: conjoint analysis to rank alternative new products (marketing instrument)

- CE respondents choose between alternatives, which are described by particular attributes

- Assumption: the value of the public good depends on the combination of its attributes

Choice Experiment

Aim:

- Understand, how respondents take decisions

Perspective:

- Causal: observable and unobservable factors lead to choice decision

Problem:

- Choice cannot exactly be foreseen

Solution:

- Calculation of probabilities based on an indicator function

Choice Experiment

- The alternatives are described by combinations of attributes
- The utility of an alternative depends on the combination of attributes
- The resulting series of elections gives information about the probability of an alternative to be elected
- The higher the level of desired attributes,…
  - …the higher the level of utility generated by an alternative and
  - …the higher the probability to be elected by the respondents

Choice Experiment

Typical Elements of CE			
OPTIONS	ATTRIBUTES	LEVELS	CHOICE
A, B, …	1, 2, 3, …	nominal ordinal cardinal	of one option (combination of attribute levels)

Implementation of a Choice Experiment

1. Characterize the decision problem
2. Select attributes and levels
3. Develop questionnaire
4. Develop experiment design
5. Collect data
6. Estimate variables of the model
7. Analyze impact on welfare and/or predict individual behavior

(based on Bennett & Adamowicz (2001))

Decision Problem concerning…

- Particular silvicultural interventions ?
- Single technical measures ?
- Determined risk reduction ?
- Entire protection forest ?

Case Study Andermatt

Protection measures 1: Wooden Stems

- after the wind throw approx. 50% of the stems are removed
- tree stumps remain (1-1.5 m high, bark removed)
- remaining stems are fixed as avalanche barriers (bark removed, pruned)

Protection measure 2: Wooden Grills

- After the wind throw all lying stems are removed.
- Wooden grills are installed as avalanche barriers.

Protection measures 3: Steel Bridges

- After the wind throw all lying stems are removed.
- Steel bridges are installed as avalanche barriers.

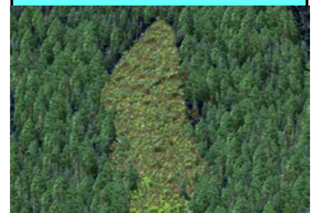
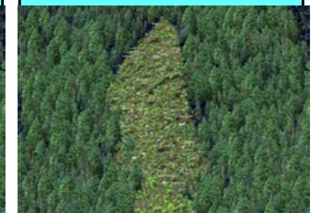
Protection measures 4: Steel Nets

- After the wind throw all lying stems are removed.
- Steel nets are installed as avalanche barriers.

Attributes and Levels

Attributes	Levels			
Damage avoidance (DA; %)	50 / 60 / 70	60 / 70 / 80	70 / 80 / 90	70 / 80 / 90
Duration (DU; years)	15 / 20 / 25	20 / 25 / 30	60 / 70 / 80	60 / 70 / 80
Starting time (ST; years)	1 / 3 / 5	1 / 3 / 5	1 / 3 / 5	1 / 3 / 5
Costs (CO; CHF)	100 / 150 / 200	200 / 250 / 300	400 / 500 / 600	400 / 500 / 600
Type (TY)	Wooden Stems	Wooden Grills	Steel Nets	Steel Bridges

Example of a Choice Set

Attribute	Option A	Option B	Option C
Type	 Steel bridges	 Wooden stems	 Wooden grills
Starting time	In 3 years	In 1 year	In 5 years
Duration	80 years	20 years	30 years
Damage avoided	80 % (8 million CHF)	60 % (6 million CHF)	70% (7 million CHF)
One-time payment per household	500 CHF	150 CHF	250 CHF

Visualisation Steel Bridges

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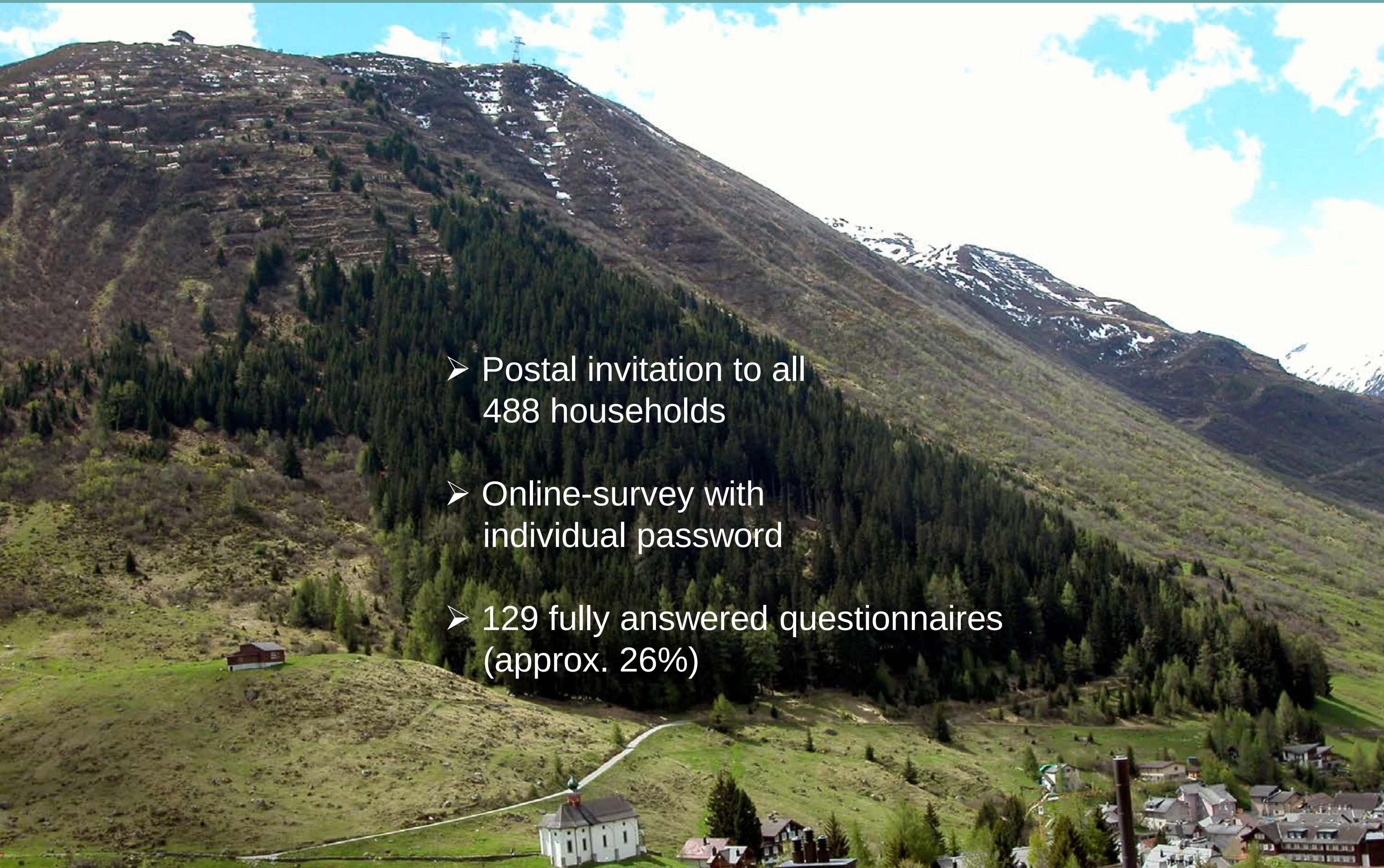

- Postal invitation to all 488 households
- Online-survey with individual password
- 129 fully answered questionnaires (approx. 26%)

Decision Rule

- Individual n chooses alternative i with the highest utility U in the choice sets

$$U_{ni} = V_{ni} + \varepsilon_{ni}$$

↓

$$V_{ni} = \beta_1 \cdot DA_{ni} + \beta_2 \cdot DU_{ni} + \beta_3 \cdot ST_{ni} + \beta_4 \cdot CO_{ni} + \beta_5 \cdot TY_{ni}$$

U_{ni}* = *Utility for individual n from alternative i
V* = *Systematic component of utility function as function of observable variables
ε = ***Random component of utility function***

DA* = *Damage avoidance (in %)
DU* = *Duration (in years)
ST* = *Starting time (in years)
CO* = *Costs (one-time payment per HH)
TY* = *Type of protection measure

Valuation of Avalanche Protection

1. Introduction

2. Methodology

3. Results

4. Conclusions

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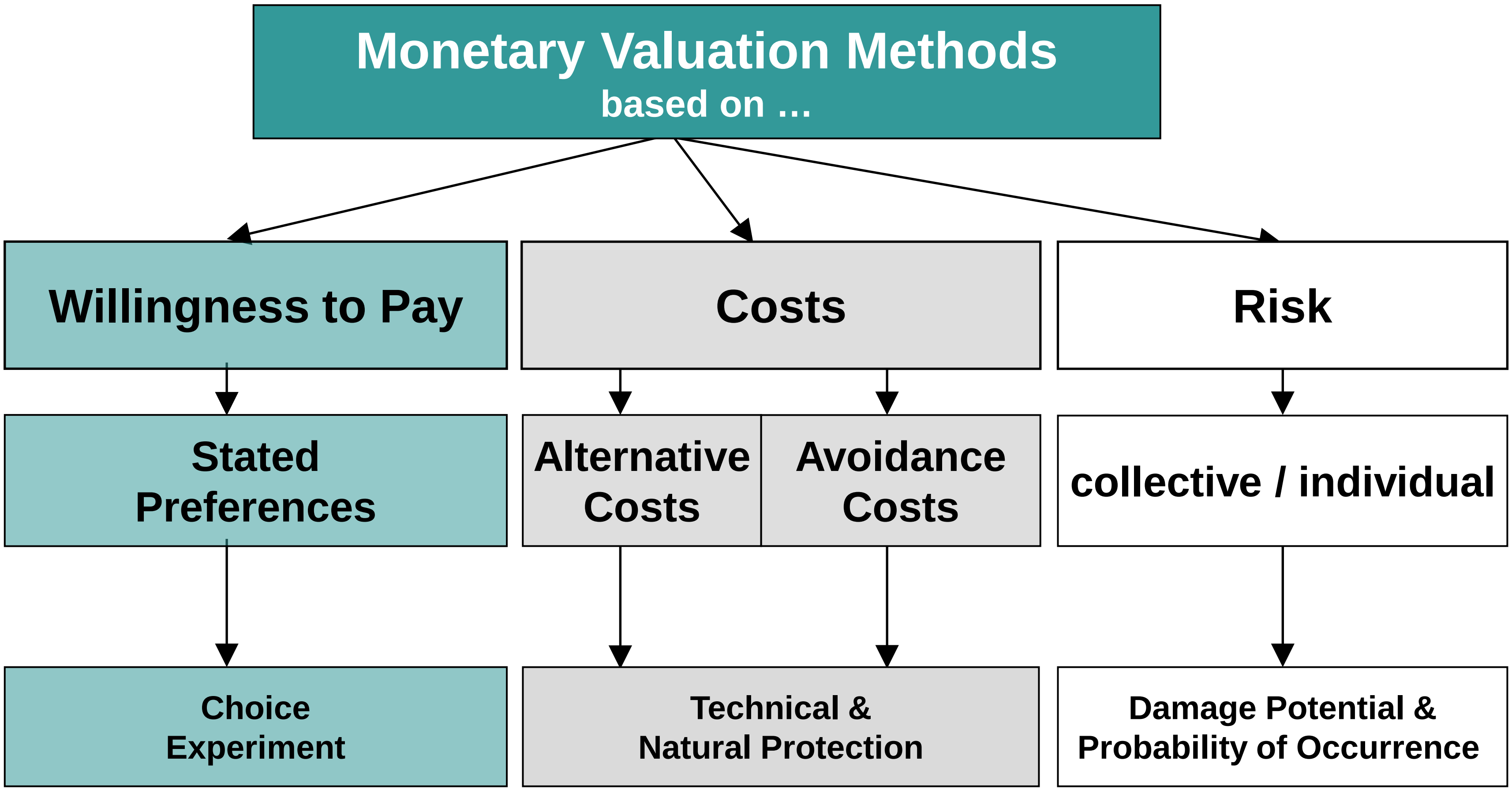
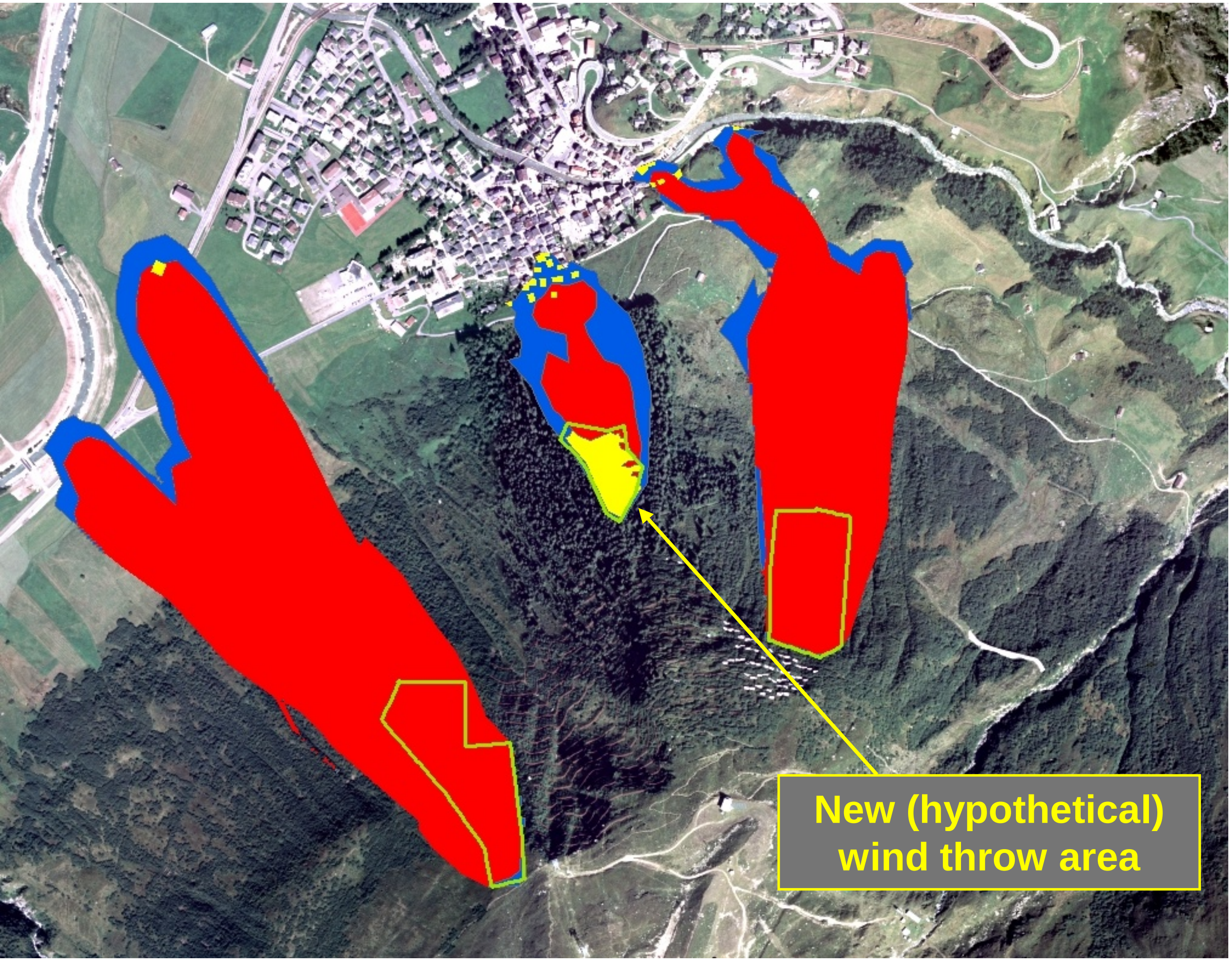


Risk Calculation



RISK
=
Damage Potential
x
Probability of Occurrence

Damage potential =
10 Mio CHF

Risk Calculation

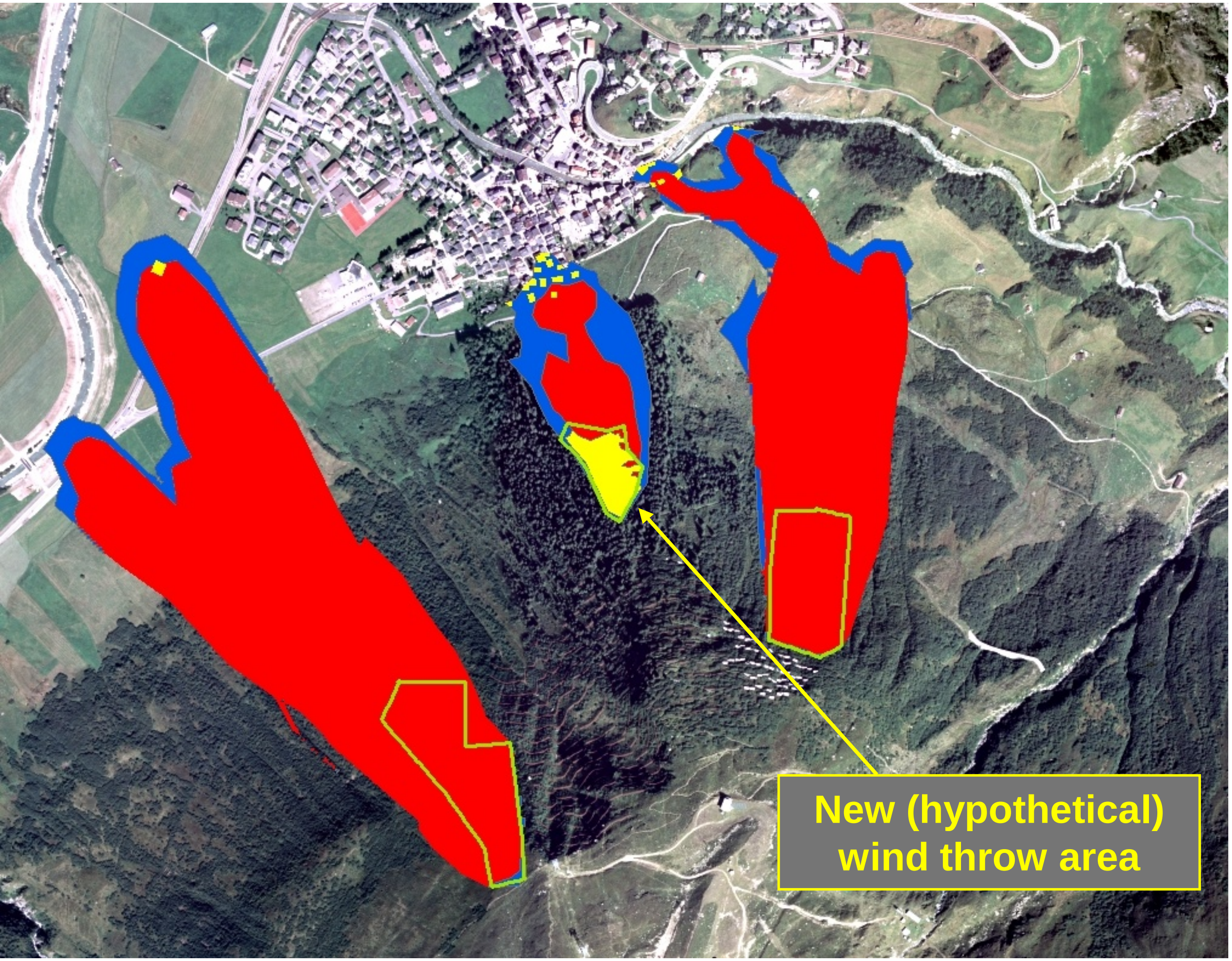
Duration (n years)	Probability of Occurrence ($P = 1 - (1 - 1/T)^n$) Occurrence every T years	Risk for T=300 (CHF)
1	0.33%	33'333
5	1.66%	165'559
10	3.28%	328'378
15	4.89%	488'500
20	6.46%	645'972
30	9.53%	953'137
40	12.50%	1'250'216
50	15.38%	1'537'539
60	18.15%	1'815'427
70	20.84%	2'084'190
80	**23.44%**	**2'344'128**
90	25.96%	2'595'529
100	28.39%	2'838'675
300	63.27%	6'327'345

RISK
=
Damage Potential
x
Probability of Occurrence

Assumptions:

Project duration (n) = 80 years
Return period (T) = 300 years
Damage potential = 10 Mio CHF

Risk Calculation



- 300-year avalanche event
- Damage potential : 10 million CHF
- Probability: 23.4% within 80 years
- **Discounted risk per household: 470 CHF**

Alternative (Replacement) Costs

		Wooden stems	Wooden grills	Bridges / Nets
Avalanche protection	(CHF/ha)	50’000	280’000	970’000
Afforestation	(CHF/ha)	30’000	30’000	30’000
Maintenance	(CHF/ha)	20’000	20’000	20’000
Total	(CHF/ha)	100’000	330’000	1’020’000
Costs in windthrow area (1.15 ha)	(CHF)	115’000	380’000	1’160’000
Discounted costs per household *	(CHF)	**60**	**200**	**600**

*) Assumptions: 488 households, 25% cost contribution

Avoidance Costs of Silvicultural Measures

		Costs
Wood cutting (incl. cleaning)	(CHF/ha)	13’800
Silviculture	(CHF/ha)	21‘200
Total	(CHF/ha)	35‘000
Discounted costs in windthrow area (1.15 ha)	(CHF)	40’000
Discounted costs per household*	**(CHF)**	**20**

*) Assumptions: 488 households, 25% cost contribution

Multinomial Logit Model Coefficients

$$V_{ni} = \beta_1 \cdot DA_{ni} + \beta_2 \cdot DU_{ni} + \beta_3 \cdot ST_{ni} + \beta_4 \cdot CO_{ni} + \beta_5 \cdot TY_{ni}$$

Attribute		coefficient	std err	t test	p value
Damage avoidance (DA)	(β_1)	0.0110	0.0044	2.48	0.01
Duration (DU)	(β_2)	-0.0049	0.0045	-1.10	0.27
Starting time (ST)	(β_3)	-0.1730	0.0186	-9.31	0.00
Costs (CO)	(β_4)	-0.0024	0.0006	-4.33	0.00
Type (TY)	(β_5)				
- Bridges		0.8510	0.3260	2.61	0.01
- Grills		0.9050	0.1210	7.47	0.00
- Nets		0.2320	0.3250	0.71	0.48
- Stems		fixed			

Willingness to Pay for Reducing Starting Time

$$WTP = -\frac{\hat{\beta}_3}{\hat{\beta}_4} \cdot DA$$

$$WTP = \frac{0.1730}{0.0024} \cdot ST = 70.90 \cdot ST$$

Starting time reduction of…	WTP one-time payment
1 year	approx. 70 CHF

WTP = Willingness to pay
β_3 = *Marginal utility of start time reduction*
β_4 = *Marginal utility of income*

Multinomial Logit Model Coefficients

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Willingness to Pay for Avoiding Damages

$$WTP = -\frac{\hat{\beta}_1}{\hat{\beta}_4} \cdot DA$$

$$WTP = \frac{0.0110}{0.0024} \cdot DA = 4.51 \cdot DA$$

Damage avoidance of…..	WTP one-time payment
100% (10.0 Mio. CHF)	approx. **450 CHF**

WTP = Willingness to pay
β_1 = Marginal utility of damage avoidance
β_4 = Marginal utility of income

Comparison of Valuation Approaches

Approach	Alternative	One-time payment
Discounted collective risk *	300-year event	470 CHF
Discounted alternative costs *	Wooden stems Wooden grills Steel bridges / nets	60 CHF 200 CHF 600 CHF
Discounted avoidance costs *	Silvicultural measures	20 CHF
Willingness to pay *	Damage avoidance	450 CHF

*) per household

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Conclusions

- Several valuation methods are available
- WTP is about as high as the estimated risk per household
- WTP would cover
  the alternative costs of wooden stems and grills
- WTP would not cover
  the costs of steel measures
- WTP exceeds by far
  the costs for silvicultural avoidance measures

Olschewski, R. (2013): How to value protection from natural hazards – A step-by-step discrete choice approach. *Natural Hazards and Earth System Sciences.* 13(4), 913-922.

Olschewski et al. (2012): Avalanche protection by forests – A choice experiment in the Swiss Alps. *Journal of Forest Policy and Economics.* 15, 108-113.

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Thanks for your attention!