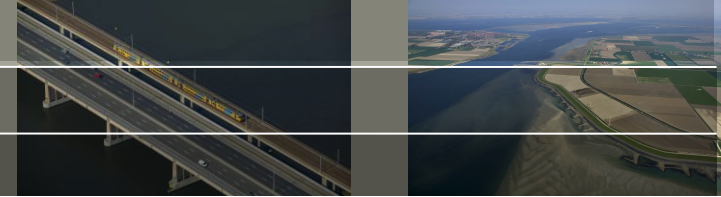


Problem description



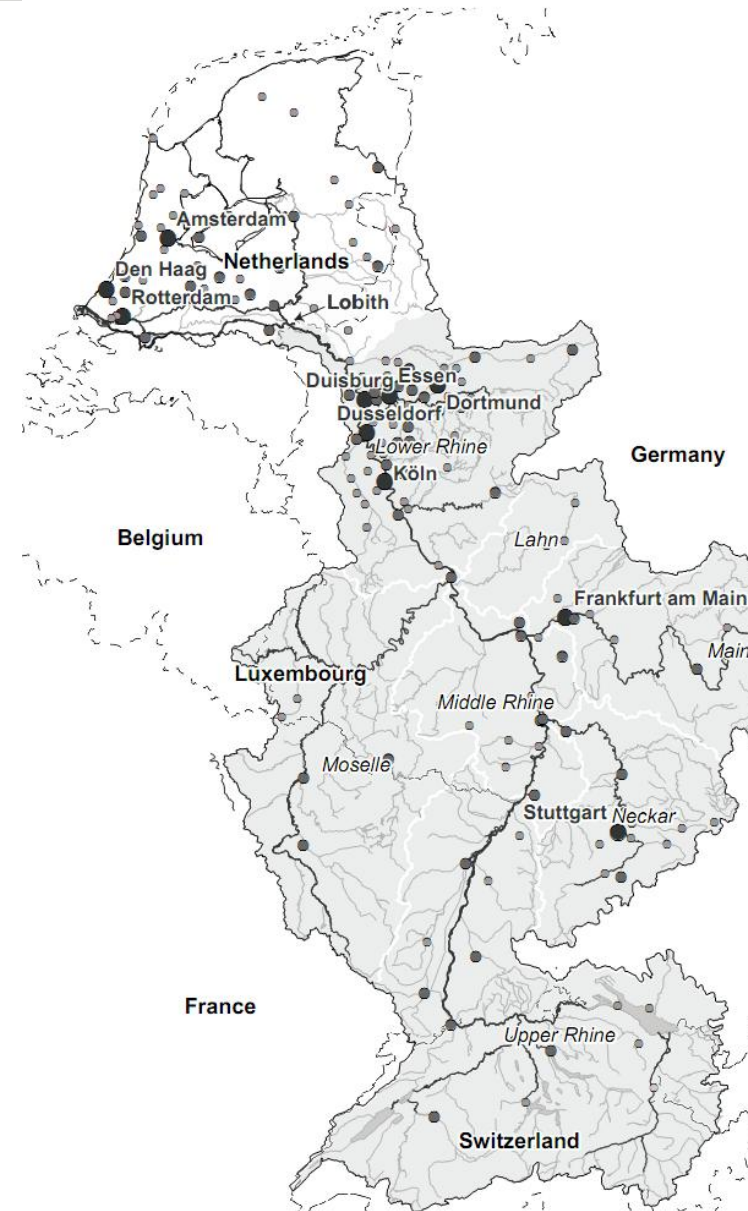
Rhine is a very important traffic route and economically important

~10 Million people live in areas at risk from extreme flooding

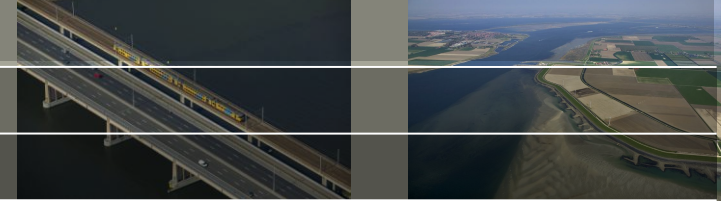
Flood events in 1993 and 1995 caused considerable damage / evacuation

Increase in flood risk is expected

- Socio-economic development
- Climate change



Research goals



Develop a flood risk model for the entire Rhine channel

- Estimate potential flood damage on the basis of up-to-date information
- Evaluate current flood risk
 - > Probability x damage
- Estimate the development of potential damage and flood risk in the future
 - > What is the main driving factor

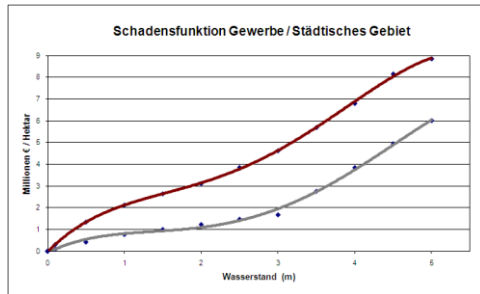
- Assess various adaptation strategies

Method: current potential damage and risk

Land Use Map



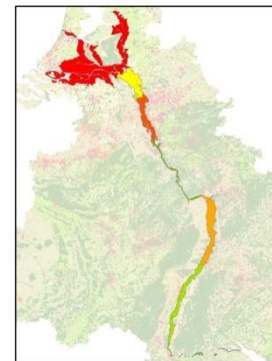
Depth damage functions (Klijn et al., 2007)



Inundation map



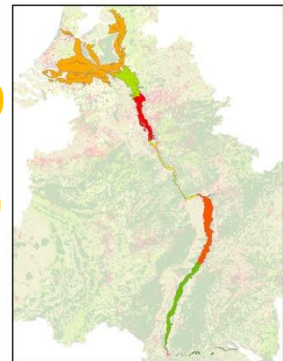
Damage map (Aggreg.)



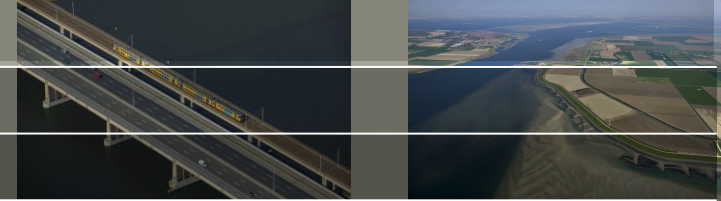
x 1/250

x 1/500

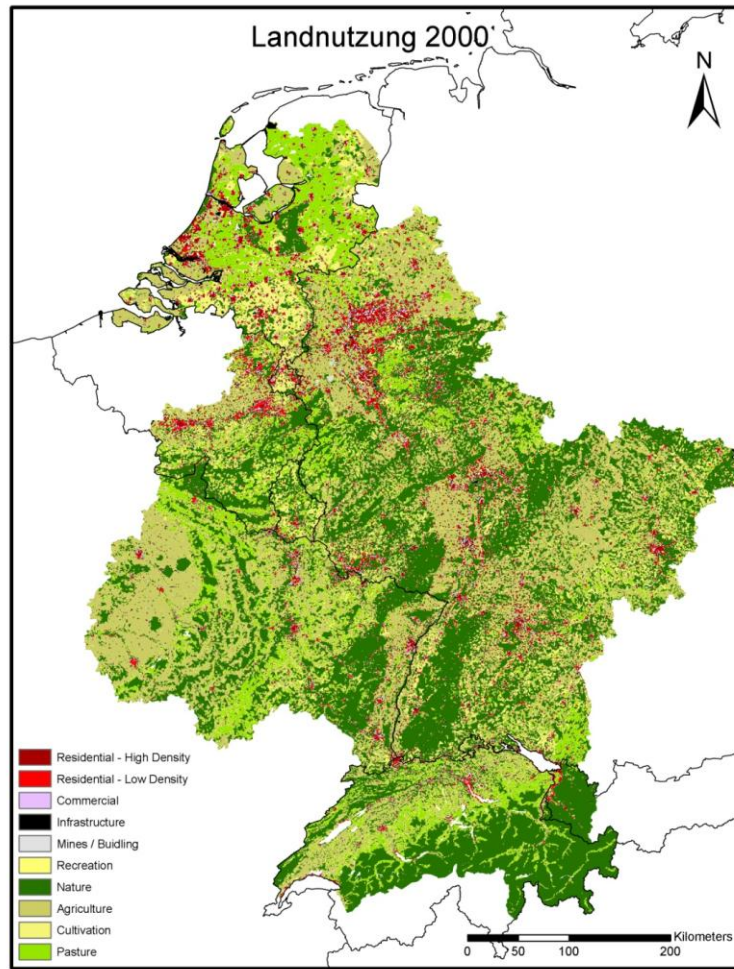
Risk map (Aggreg.)



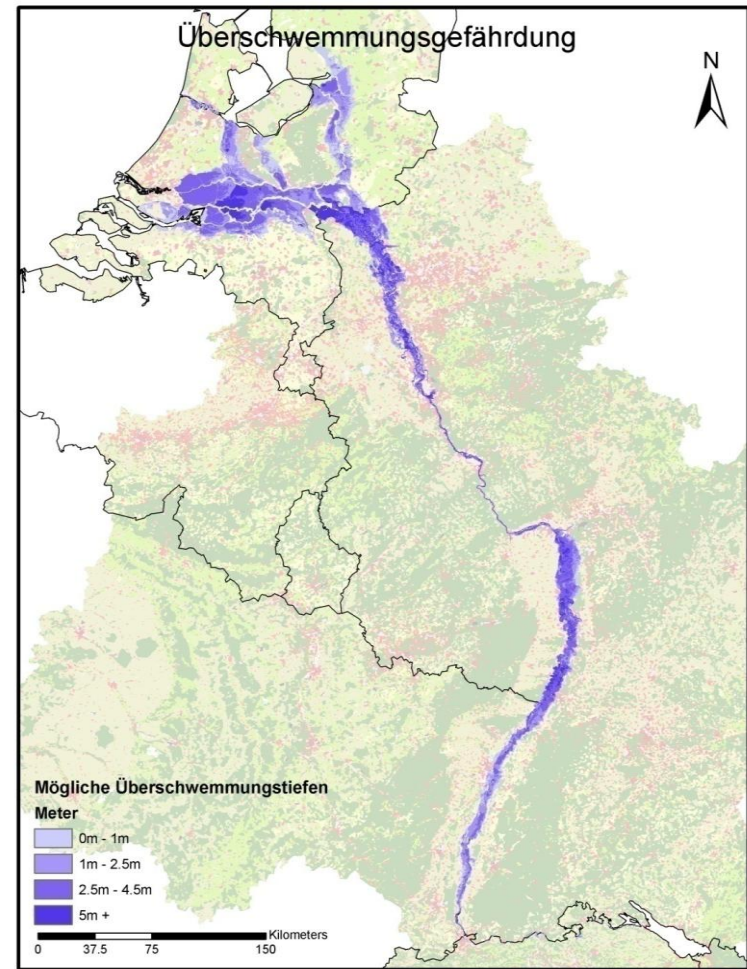
Method: maps



CORINE 2000



Rhine Atlas (2001) / 'Risicokaart'

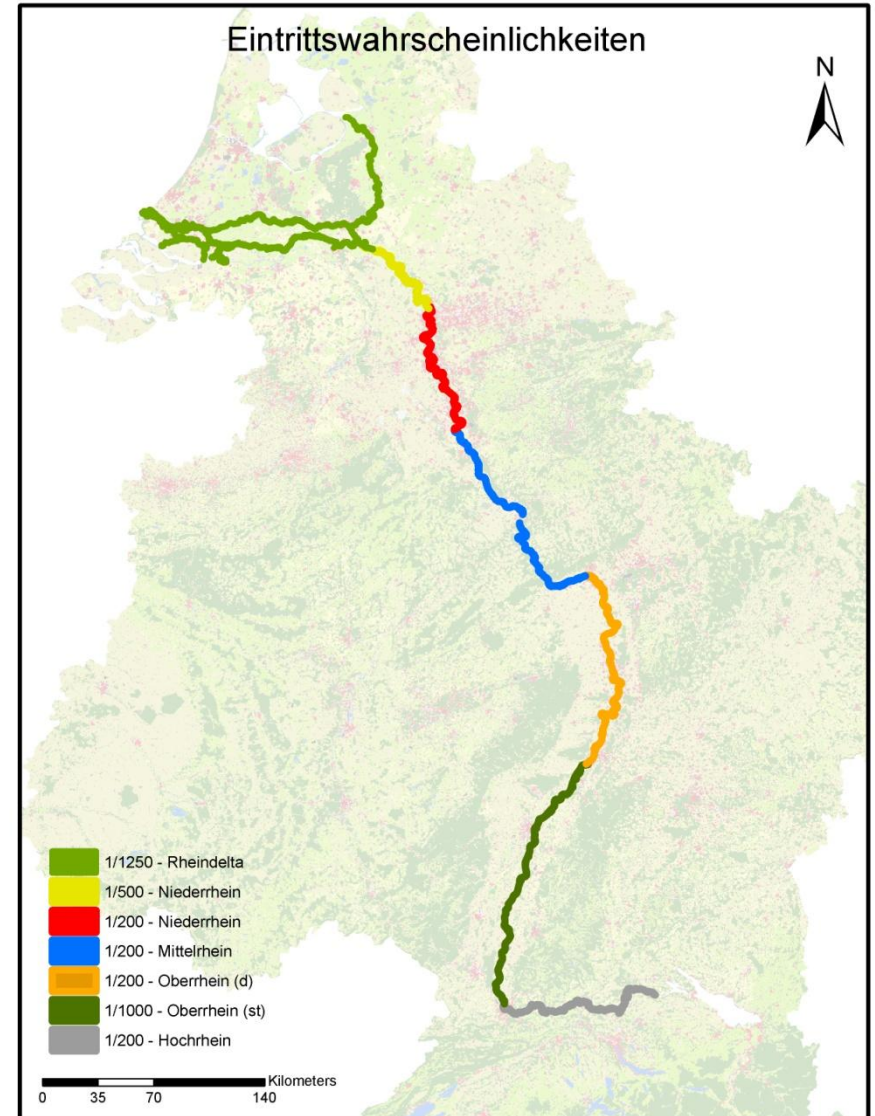


Method: flooding probabilities

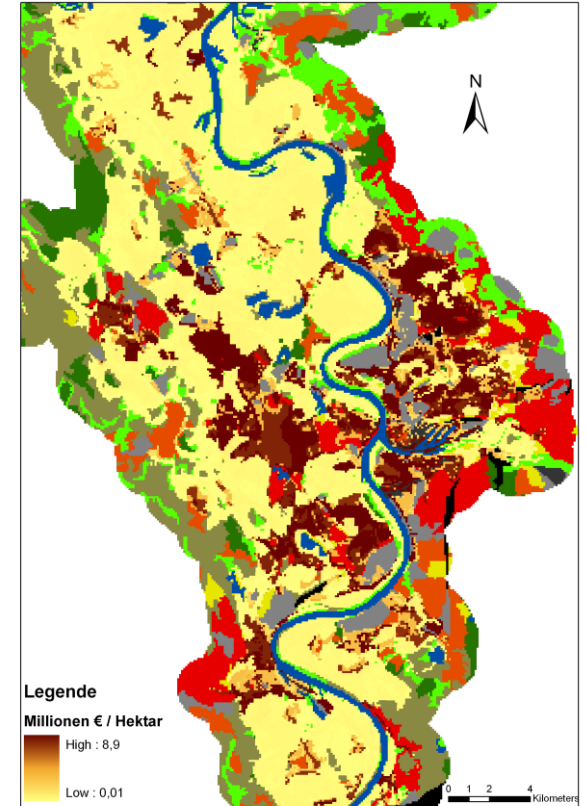
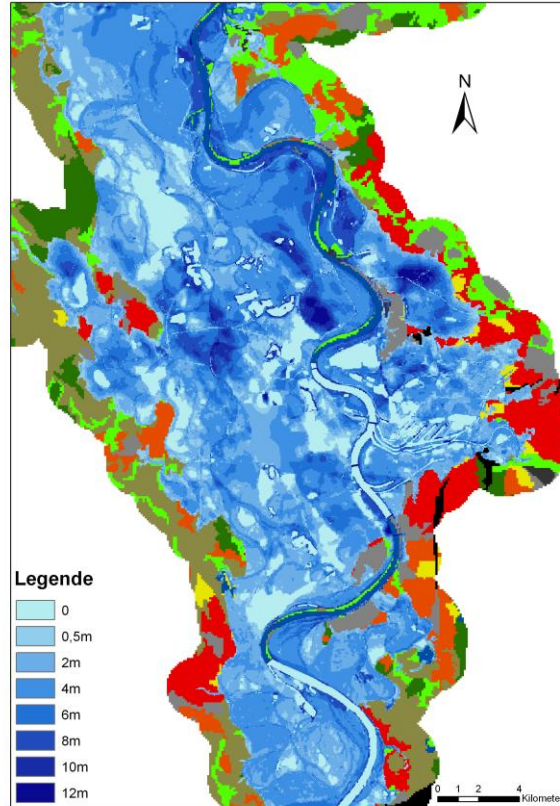
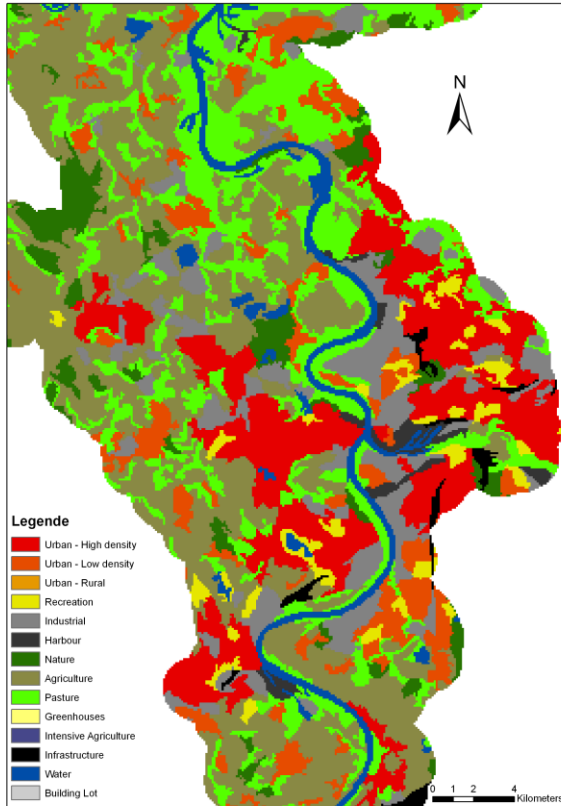
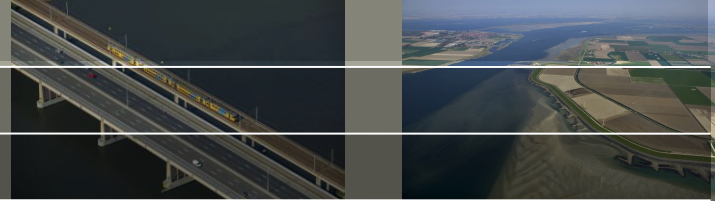
Safety levels:

- Dutch delta: design standard
- Other sections: based on a report by ICPR and expert judgement (interviews)

	Return periods
Alpine	1/200
Upper Rhine	1/1000
Upper Rhine	1/200
Middle Rhine	1/200
Lower Rhine	1/200
Lower Rhine	1/500
Rhine delta	1/1250

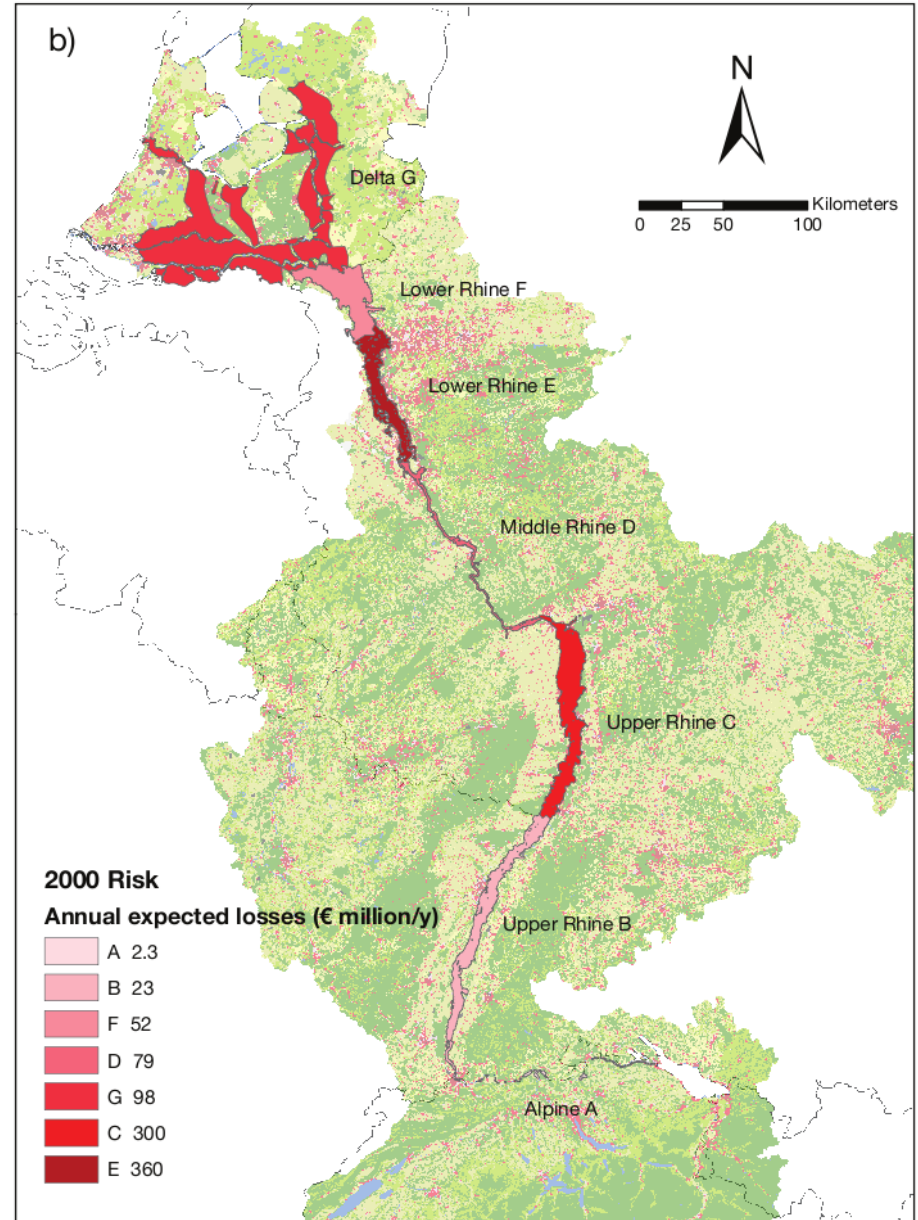
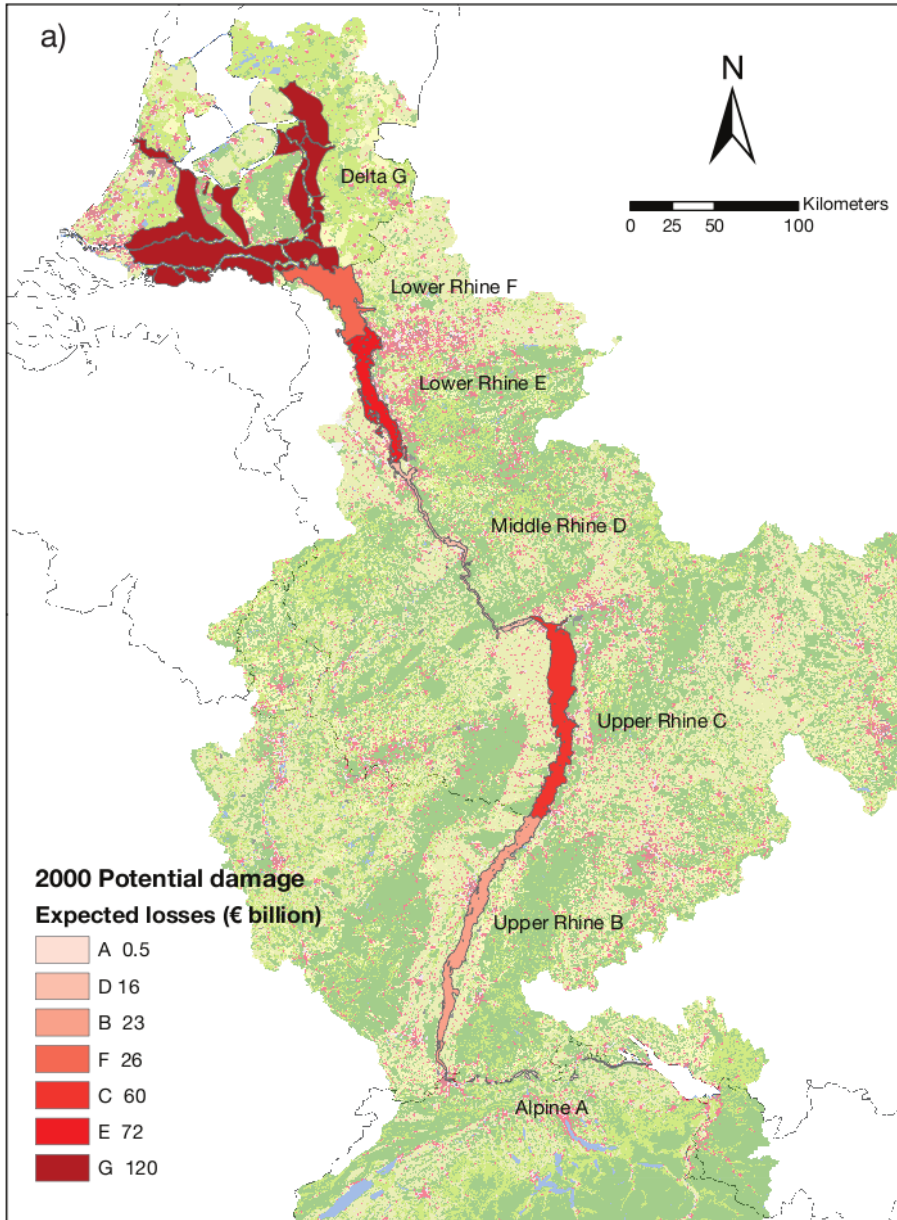
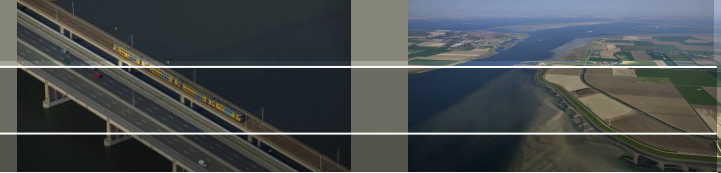


Results

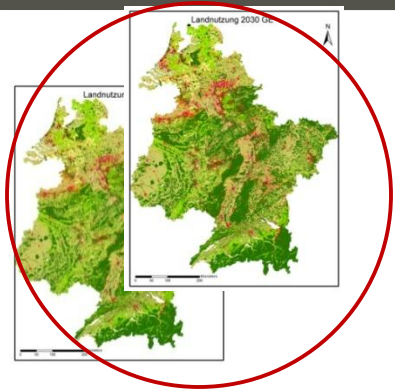


Rhine at Duisburg

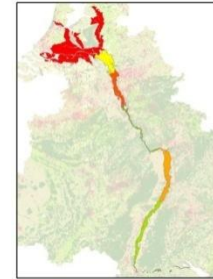
Results: aggregated



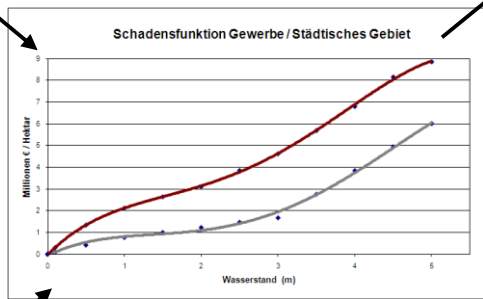
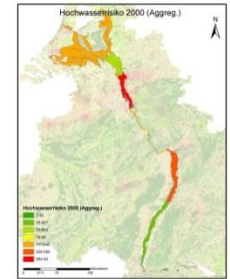
Method: future flood risk in 20309



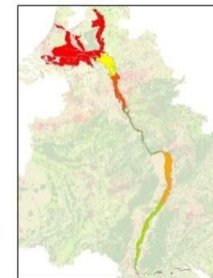
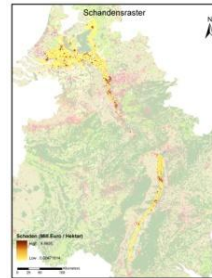
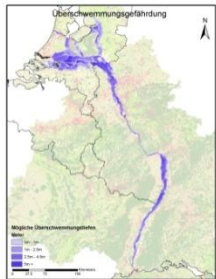
Global Economy and climate scen 1



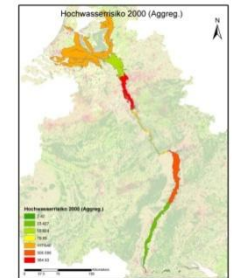
x 1/150
X 1/400



Regional Communities and climate scen 2



x 1/200
X1/450



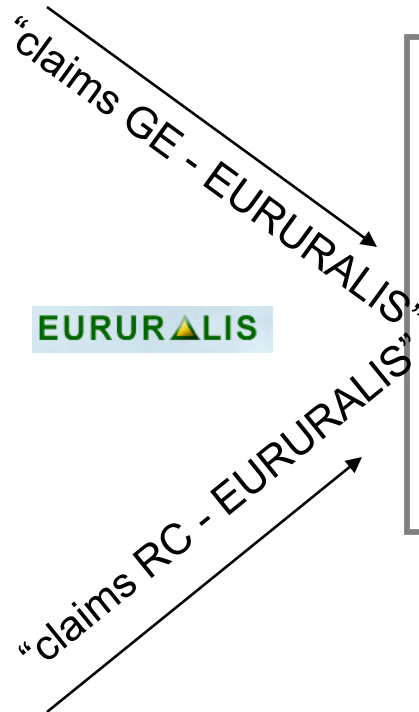
Method: socio-economic scenarios

Global Economy

- Strong population and economic growth
- International economic integration
- Strong role of the individual
- Private interests

Regional Communities

- Low economic and population growth
- National / regional focus
- Strong role of governments
- Environmental regulations



„Land Use Scanner“

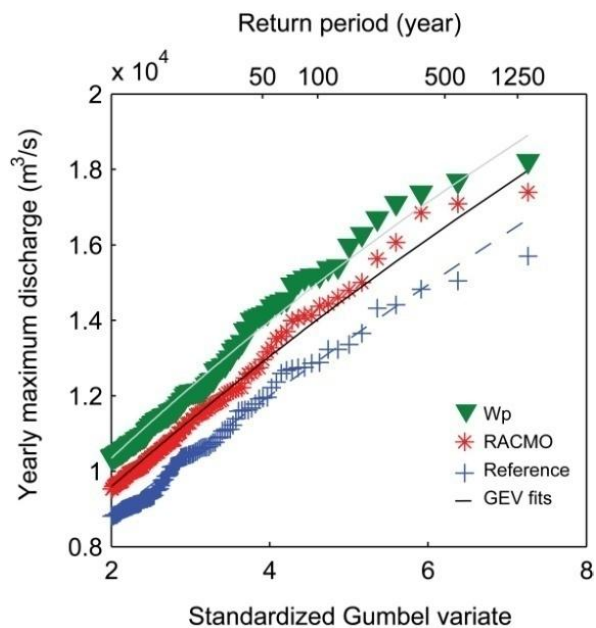
- Suitability Maps
 - Flood zones
 - Nature areas
 - Retention areas
- Distance Maps
- DEM

(Rietveld & Hilferink, 1999;
Loonen and Koomen, 2008)

Method: climate change scenarios

- Taken from Te Linde et al., 2010
- Long time series (weather generator)
- 'Low' scenario and 'high' scenario

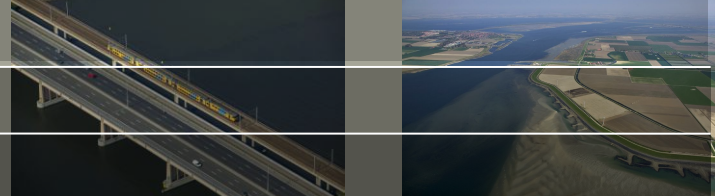
Assumption: no
dike raise



For every section:

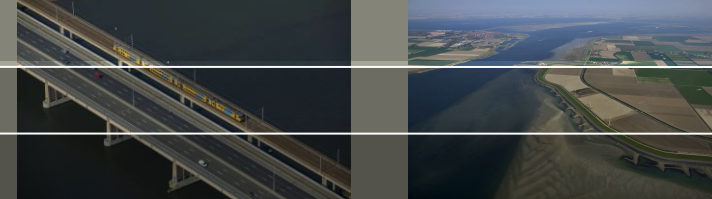
p Ref	p Scen1	p Scen2
0.050	0.062	0.0129
1/200	1/160	1/77

Results



Region	Reference situation			RACMO and RC			Wp and GE		
	p	EUR bln	EUR mln/yr	p	EUR bln	EUR mln/yr	p	EUR bln	EUR mln/yr
Alpine A	0.0050	0.5	2.3	0.0072	0.4	2.9	0.0157	0.5	8.1
Upper Rhine B	0.0010	23	23	0.0014	23	33	0.0038	27	110
Upper Rhine C	0.0050	60	300	0.0062	64	400	0.0129	75	970
Middle Rhine D	0.0050	16	79	0.0063	13	82	0.0125	19	2
Lower Rhine E	0.0050	72	360	0.0075	81	600	0.0125	91	1100
Lower Rhine F	0.0020	26	52	0.0031	31	95	0.0062	38	240
Delta	0.0008	120	98	0.0015	131	200	0.0023	150	340
Total		230	920		340	1400		400	3000

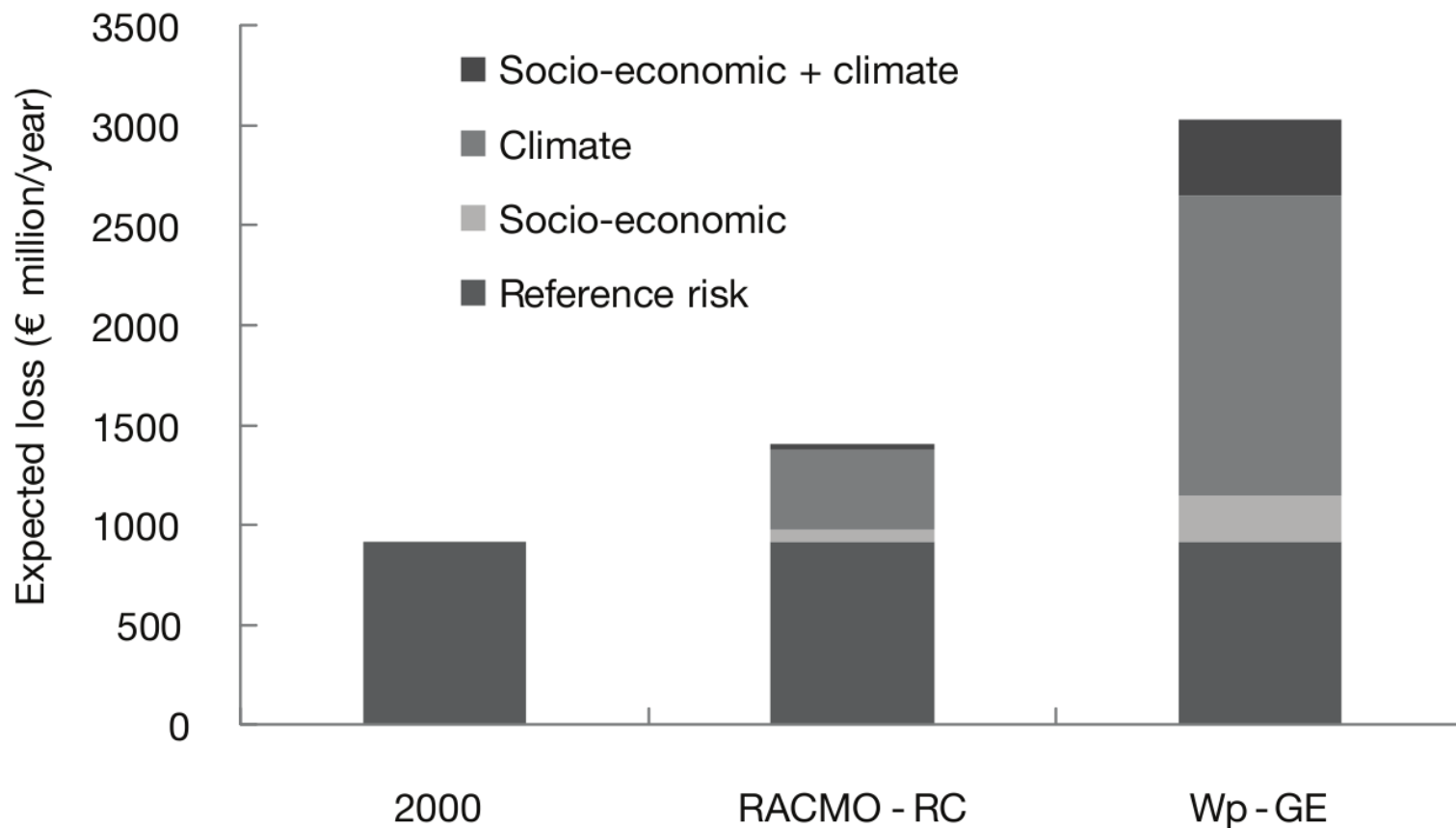
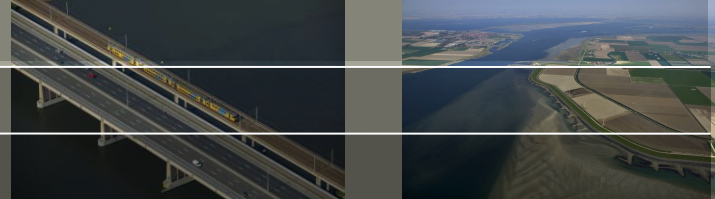
Results: driving factor



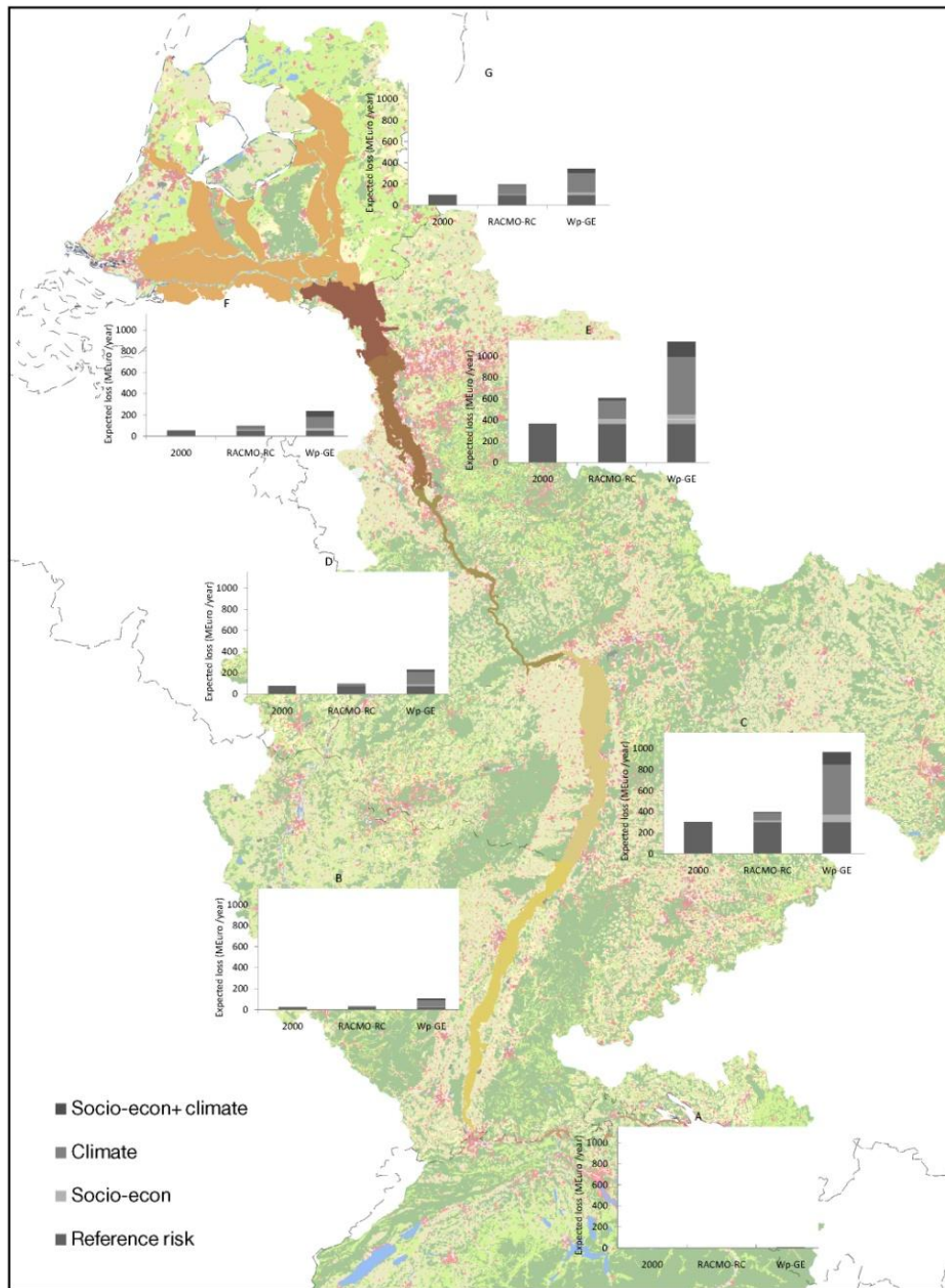
Basin-wide expected losses (risk) in MEur/year

		Socio-economic scenario		
		Reference	RC	GE
Climate scenario	Reference	920	980 (6.5%)	1200 (25%)
	RACMO	1300 (43%)	1400 (53%)	1600 (79%)
	Wp	2400 (160%)	2600 (180%)	3000 (230%)

Results



Results



Conclusions and recommendations

- Highest potential damage NL: 120 BEuro
- Highest flood risk in Nordrhein Westfalen: 360 MEuro / yr
- 2000 – 2030: 53 – 230 % increase in basin-wide flood risk
- ~ three quarters climate change

- Probability of extremes is very uncertain, impact of climate change even more
 - damage reduction seems robust adaptation measure

- Method needs improvement:
 - Inundation simulation
 - Damage estimates
 - Estimates of safety levels

Thank you

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