



Flood risk developments in the Rhine Basin and its Delta

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Content

- Study Area
- Problem description and research goals
- Current flood damage potential and risk
 - Method and results
- Future drivers of flood risk in the Rhine Basin
 - Methods and results
- Evaluation of current adaptation strategies
 - Flood Action Plan of the International Commission for the protection of the Rhine (ICPR)

Study Area



Problem description

- Rhine is a very important traffic route and economically important
 - ~10 million people live in areas at risk from extreme flooding (ICPR)
 - Flood events in 1993 and 1995 caused considerable damage / evacuation
 - Increase in flood risk is expected
 - Socio-economic development / Global warming
- Requires better understanding of potential flood risk developments
- Need to evaluate effectiveness of adaptation strategies



Research Goals

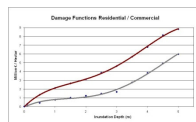
- Develop a flood risk model for the entire Rhine channel
 - Estimate potential flood damage
 - Estimate flood risk
 - > Probability x damage
- Estimate the developments in future flood risk
 - What is the main driving factor
- Assess different adaptation strategies (Flood Action Plan, ICPR)

Current flood risk - Method

Land Use Map



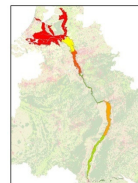
Depth-damage Functions



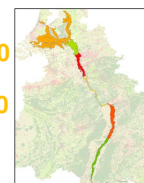
Damage grid



Damage map (Aggreg.)



Risk map (Aggreg.)



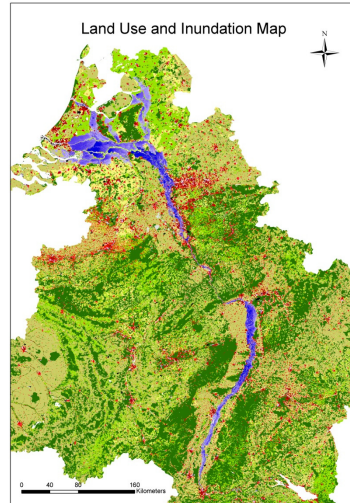
Inundation Map



x 1/250
x 1/500

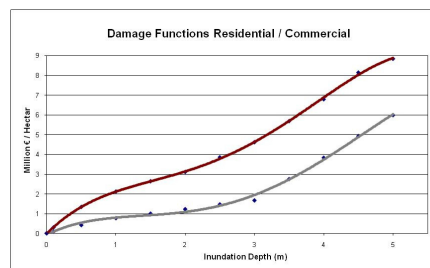
Current flood risk - Method

- Land Use
 - CORINE
 - Switzerland 1990
 - Population density
- Inundation
 - Rhine Atlas (ICPR, 2001)
 - NL: Provincial „Risikokaart“



Current flood risk - Method

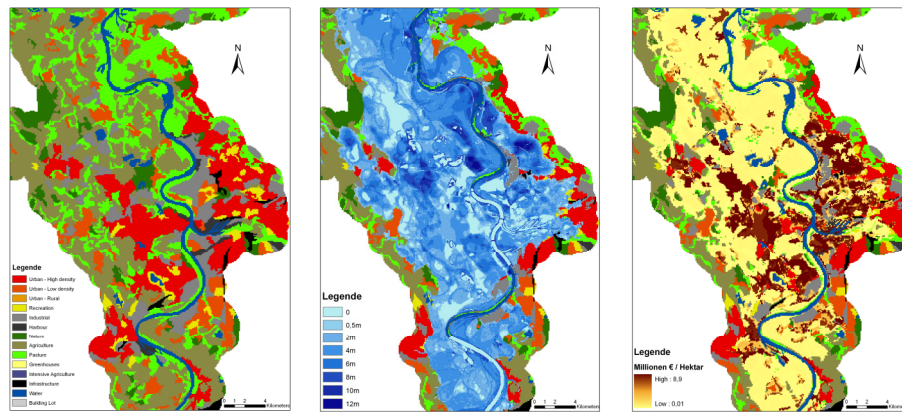
- Damage Functions (Klijn et al., 2007)
 - High uncertainty of DF in terms of absolute values
 - Relative changes are of interest
 - > Results more robust
 - > Factor 1.3 (Bubeck et al. (in prep.) / De Moel and Aerts, 2009)
- Return periods
 - ICPR
 - Report No. 153d (Hval)



Current probabilities

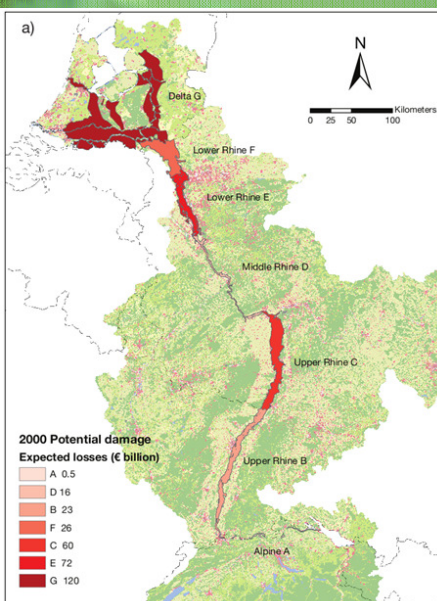
	Return periods
Alpine	1/200
Upper Rhine(st)	1/1000
Upper Rhine (d)	1/200
Middle Rhine	1/200
Lower Rhine	1/200
Lower Rhine	1/500
Rhine delta	1/1250

Current flood risk - Results

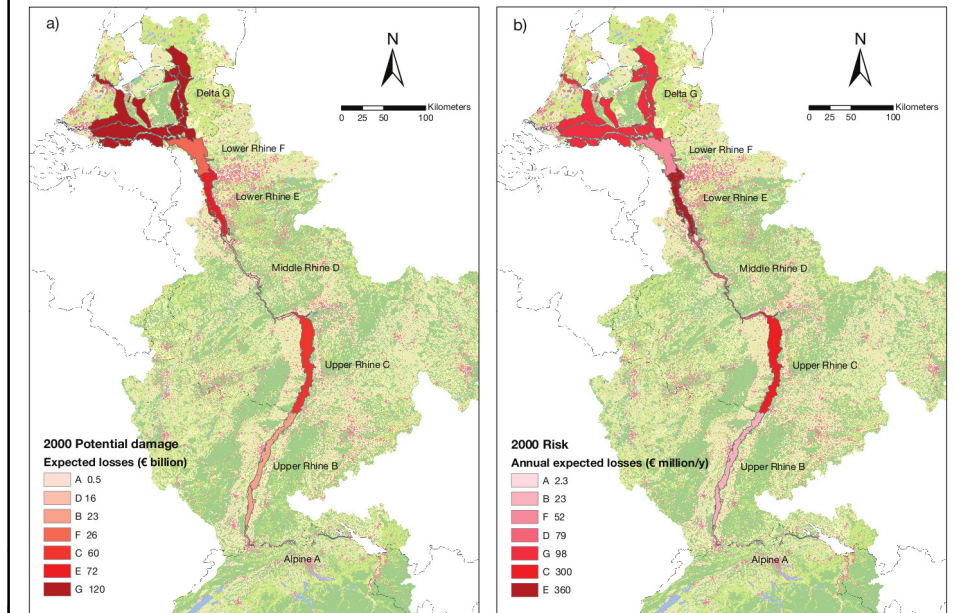


Rhine at Duisburg

Current flood damage potential and risk - Results



Current flood damage potential and risk - Results



Current flood risk - Results

<u>Country</u>	<u>Risk (Mill. Euro / year)</u>
Switzerland	1
France	9
Netherlands	99
Germany	810

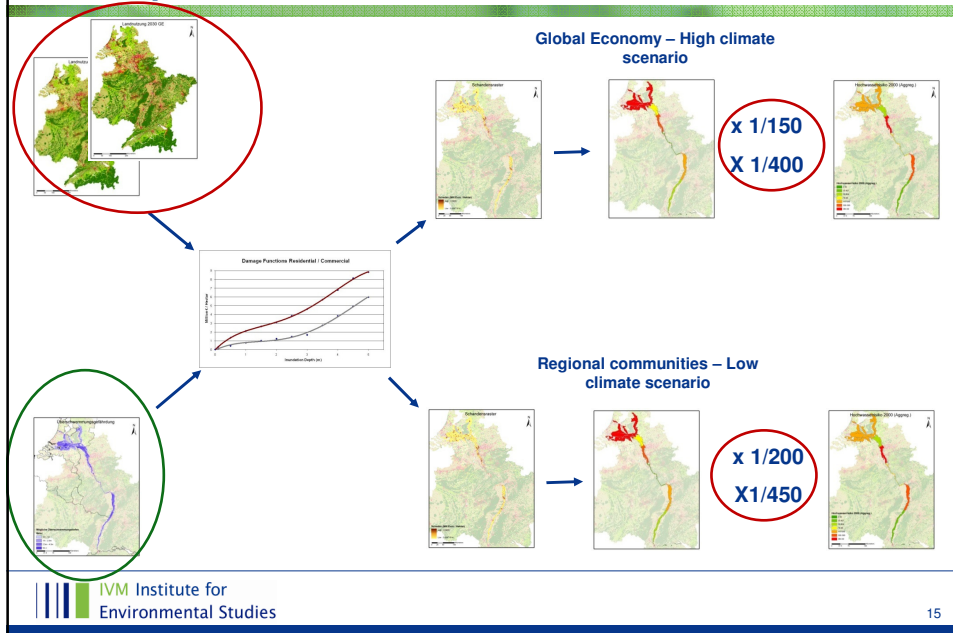
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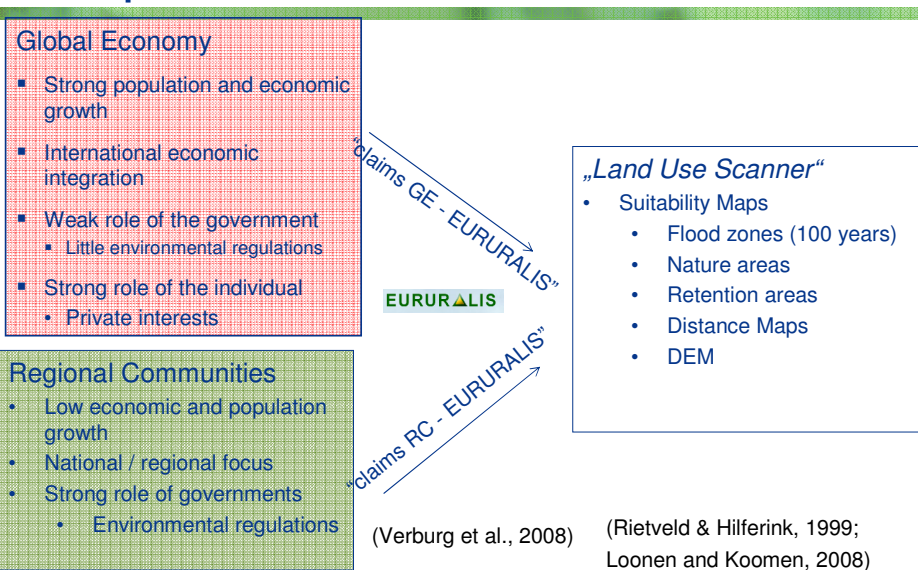
Development of Future Flood Risk

"It is difficult to make predictions, especially about the future"

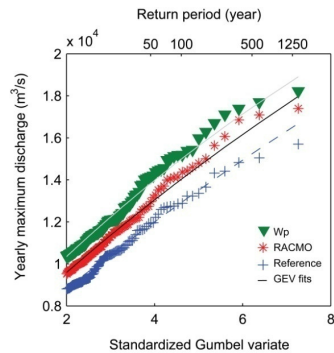
Development of Future Flood Risk – Method



Development of Future Flood Risk – Method



Development of Future Flood Risk – Method

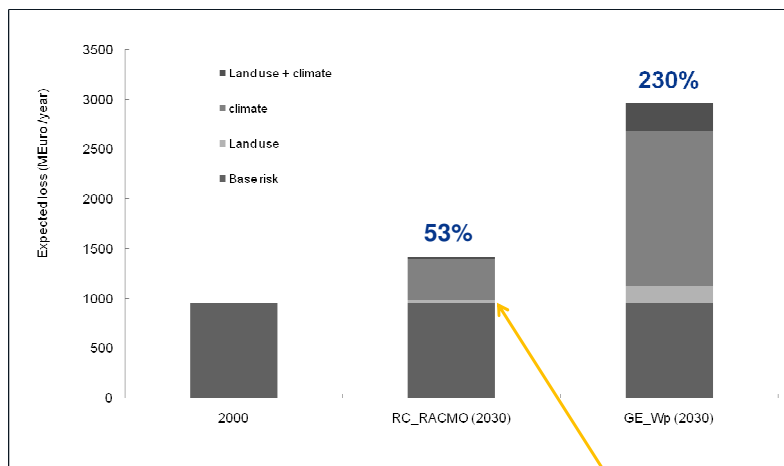


Assumption: No flood control measures

	RACMO	Wp
Region	<i>p</i> incr.	<i>p</i> incr.
Alpine A	1.4	3.1
Upper Rhine B	1.5	3.9
Upper Rhine C	1.3	2.6
Middle Rhine D	1.3	2.5
Lower Rhine E	1.5	2.5
Lower Rhine F	1.5	3.1
Delta G	1.9	2.9

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

Development of future flood risk - Results



2000 – 2030: 30 Mill. € = 1 Mill. € / year
1990 – 2000: 19,2 Mill. € = 1,92 Mill. € / year

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Evaluation Flood Action Plan (ICPR)



Flood Action Plan

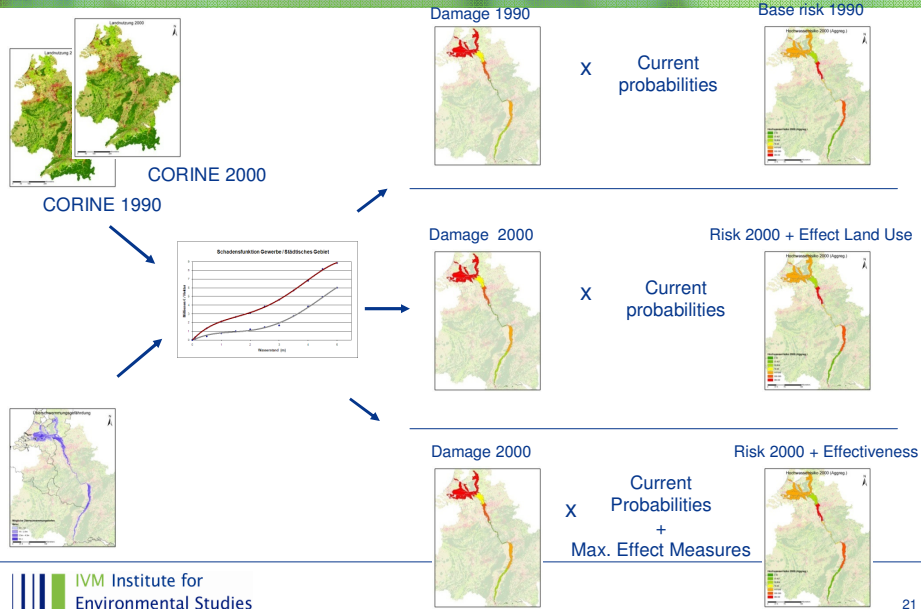
Source: ICPR

- Adopted 22nd January 1998 by the ICPR

Goals

- **Reduce flood risk by 10% in 2005 and 25% in 2025**
- **Reduce peak water level**
- Improve flood awareness
- Improve early warning system

Evaluation Flood Action Plan (ICPR) - Method



Evaluation Flood Action Plan (ICPR) - Results

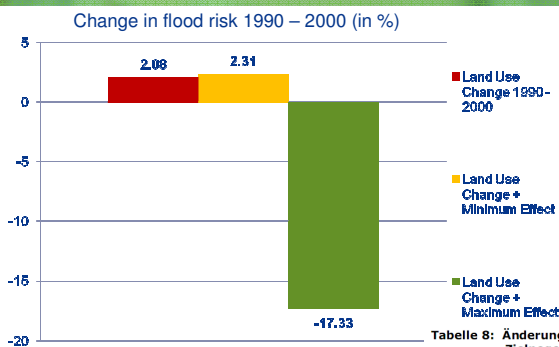


Tabelle 8: Änderung der Jährlichkeit, gegliedert nach HW-Bereiche an den Zielpegeln (scheitelwertbezogen)

Pegel		Q/T-Änderungen (Zustand 2005 - 1995) nach HW-Bereich			
		HQ 10	HQ 100	HQ 200	HQ 1000 / HQ 1250
Maxau	Minima	+/- 0	+ 15	+/- 0	-
	Maxima	+ 2	+ 45	+ 130	-
Worms	Minima	+/- 0	+ 10	+ 20	-
	Maxima	+ 5	+ 30	+ 80	-
Kaub	Minima	+/- 0	+/- 0	- 5	-
	Maxima	+/- 0	+ 15	+ 15	-
Köln	Minima	+/- 0	+/- 0	+/- 0	+/- 0
	Maxima	+/- 0	+ 10	+ 20	+ 35
Lobith	Minima	+/- 0	+/- 0	+/- 0	+/- 0
	Maxima	+/- 0	+ 10	+ 20	+ 120

Conclusions and recommendations

- 2000-2030: 53-230% increase in basin-wide flood risk
 - About three quarters can be attributed to climate change
- Probabilities of extremes are very uncertain, impact of climate change even more
 - damage reduction seems robust adaptation measure

Method needs improvement:

- Inundation simulation
- Estimates of safety levels
- Damage estimates

Thank you!

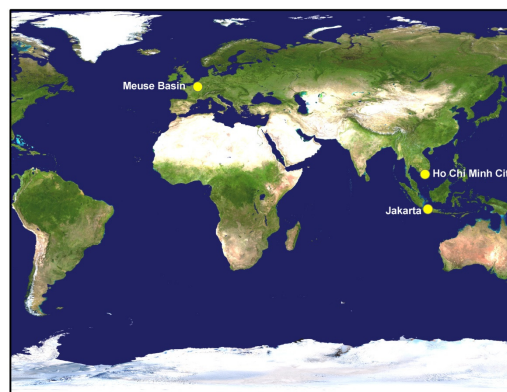
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<http://www.adaptation.nl>



Developments of future flood risk - Results

		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%)

Development of Future Flood Risk – Method

