Assessing the dynamic feedbacks between the water system and society

9th Meuse Symposium, Liege, September 12th , 2023

Prof. Dr. Jeroen Aerts

IVM Institute for Environmental Studies
VU University Amsterdam

2021 Summer Floods (Netherlands)

Return periods up to 1/100 and 1/1000 years

2500 flooded households

600 flooded firms

50,000 evacuated

€400-€500 million economic damage

Survey distributed among 11,000 (nearly) flooded addresses

“Flood measures at building scale reduce flood risk”

“Government needs to take care of this”

OVERSTROMINGSBESTENDIG

Aangepast bouwen beperkt de schade bij hoogwater enorm

MAASTRICHT
DOOR THEO SNIEKERS

'Overstromingsbestendig' bouwen kan de schade bij hoogwater met tienduizenden euro's beperken. Dat is een van de hoofdconclusies uit recent gepubliceerd wetenschappelijk onderzoek naar de watersnoodramp in Limburg in juli 2021.

Aan het onderzoek van de Vrije Universiteit (VU) Amsterdam en kennisinstituut Deltares lag een enquête onder 1500 Limburgse huishoudens ten grondslag. Die vond ongeveer een half jaar na het hoogwater plaats. Van enkele honderden huishoudens overstroomde de woning.

Waterdicht

Volgens hoofdonderzoeker Thijs Endendijk kan veel onheil worden voorkomen „als je bij de bouw en renovatie van woningen in risicovolle gebieden rekening houdt met overstromingsgevaar". Door te werken met waterdichte materialen bijvoorbeeld, zegt de milieu-econoom van het Instituut voor Milieuvraagstukken van de VU. Ook het hoger plaatsen van elektrische apparaten helpt, net als het bouwen van woningen op verhoogde grond. De schade aan huizen kan dan met 20 procent worden verlaagd, die aan de inboedel zelfs met 40 procent.

Noodmaatregelen helpen ook. Die kunnen de schade aan woningen met bijna 30 procent van de herbouwwaarde beperken, leert het onderzoek. Gemiddeld is dat ongeveer 40.000 euro. De averij aan de inboedel kan met 25.000 euro worden teruggebracht.

Verrast

„Ongeveer de helft van de huishoudens kon dit soort maatregelen in 2021 nemen", zegt promovendus Endendijk. Maar voor veel inwoners in het Geulgebied was dit niet meer mogelijk, weet hij. „Zij werden verrast door het snelstijgende water." Langs de Geul kwamen waarschuwingen niet of laat. De gemiddelde schade per huishouden daar was 65.000 euro, langs de Maas 'slechts' 17.000 euro.

De totale gemiddelde schade is 50.000 euro, blijkt uit de enquête. Die wijst ook uit dat getroffen Limburgers daarvan slechts 60 procent vergoed kregen of dat verwachtten. Dat slachtoffers achterbleven met veel restschade, bevestigt het beeld dat oprees uit onderzoek van *De Limburger*.

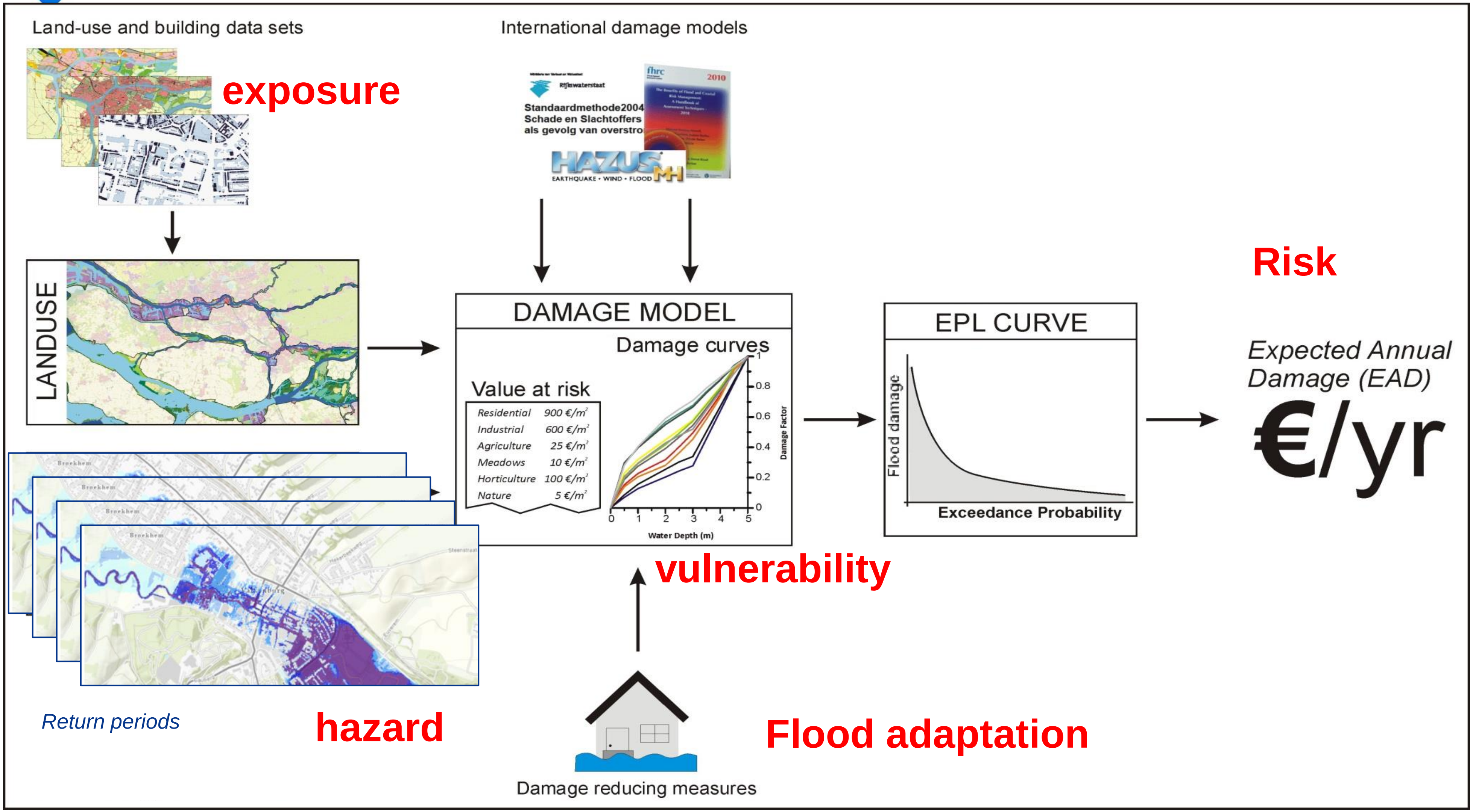
REGIO // 7

De Limburger ,
July 2023

* What factors drive people to implement flood measures?

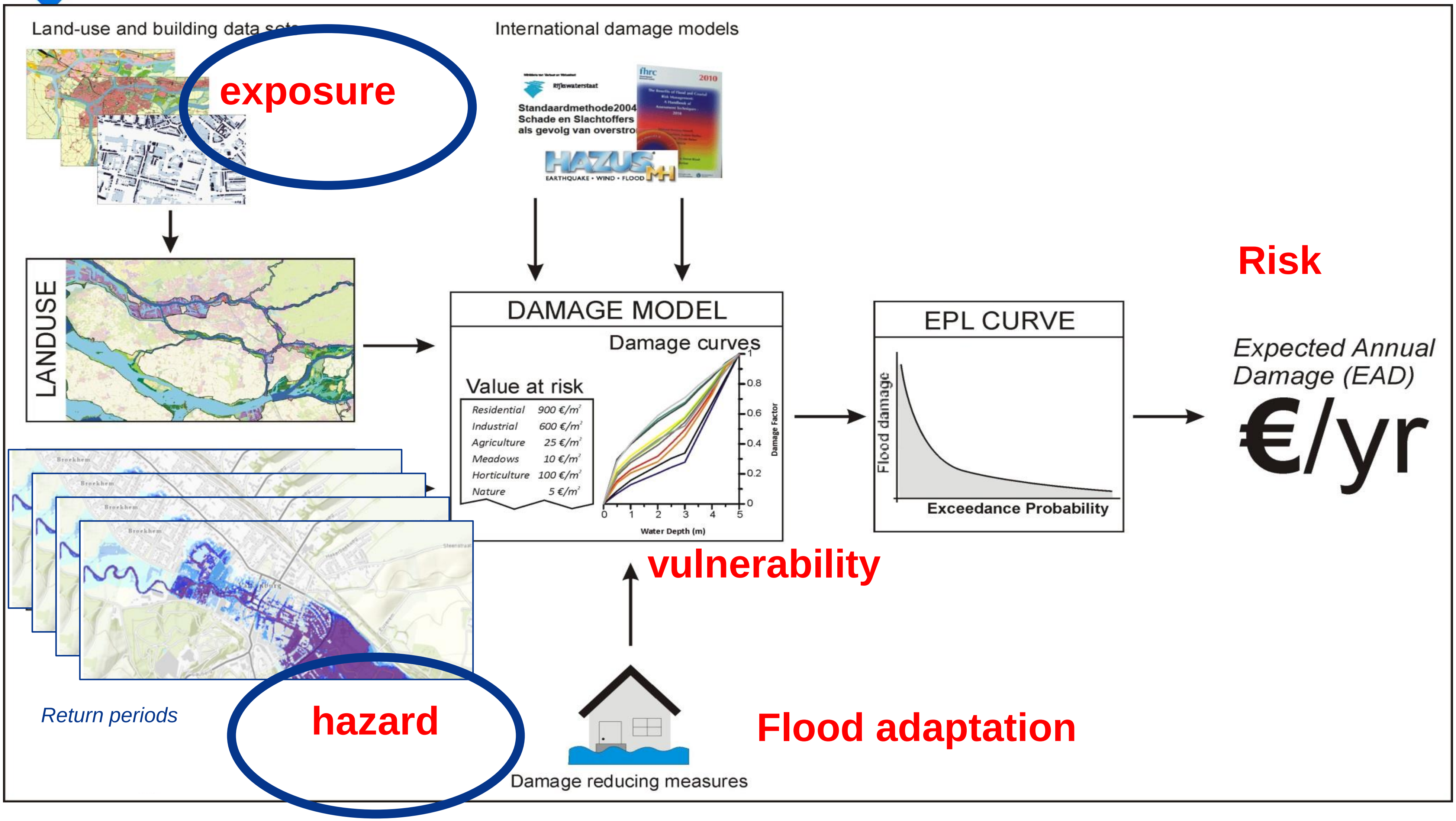
* Can flood risk assessment modelling capture these flood adaptation dynamics?

Flood risk assessment



De Moel et al., 2013

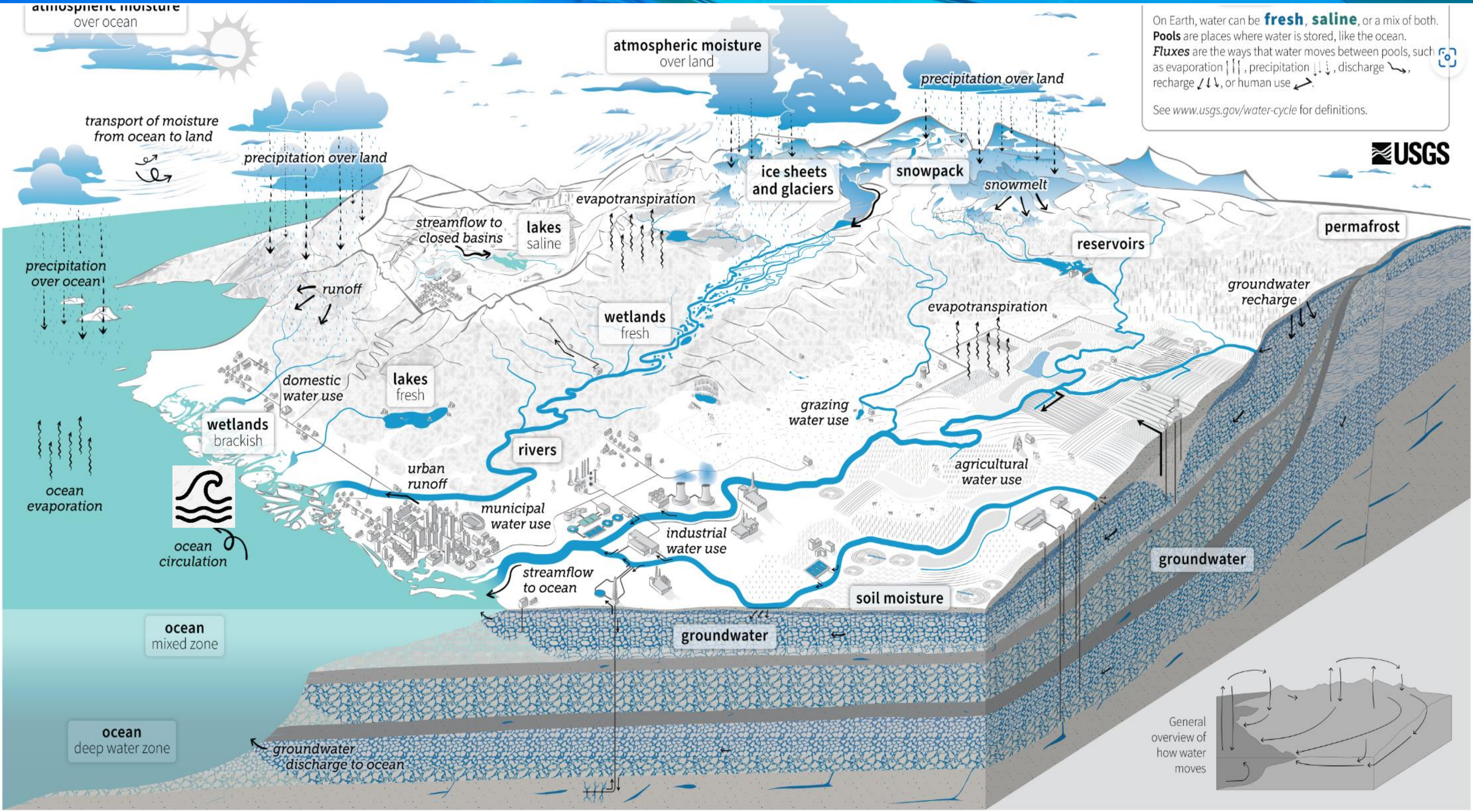
Flood risk assessment



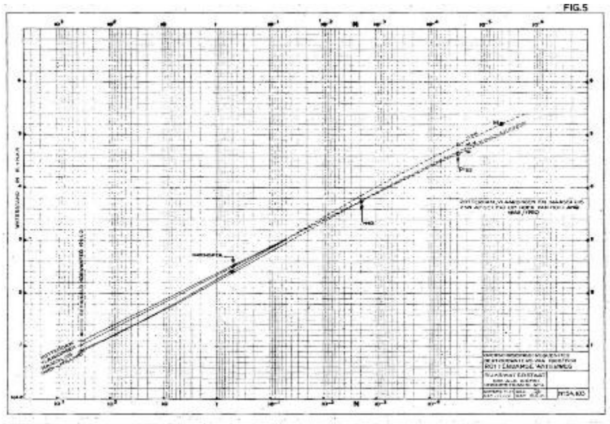
De Moel et al., 2013

Flood hazard

Role of Hydrology?



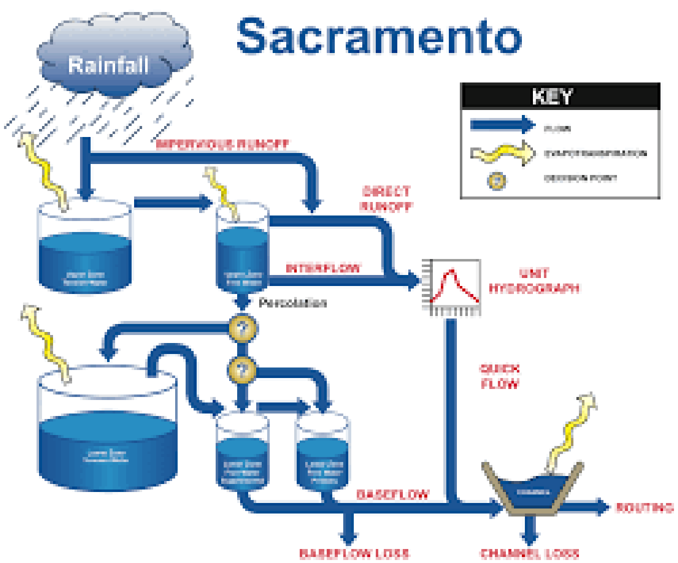
Flood Hazard Simulation



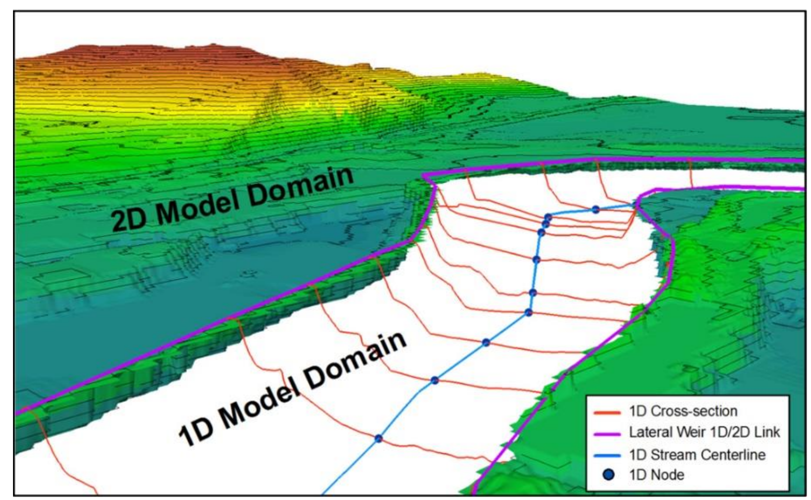
GUMBEL'S EXTREME VALUE I DISTRIBUTION: A NEW LOOK

By Dennis P. Lettenmaier,[1] A. M. ASCE
and Stephen J. Burges,[2] M. ASCE

(1982)



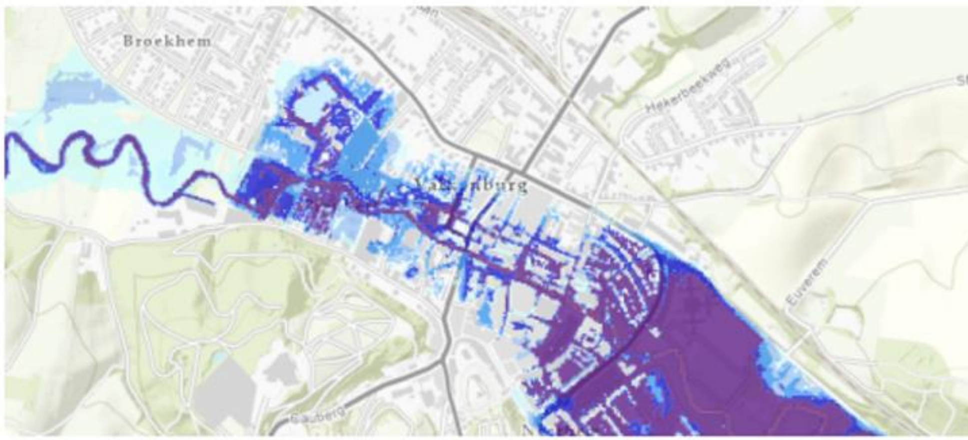
Rainfall-runoff models. *T.V. Hromadka (1990)*



Hydrodynamic models

Flood maps Geul tributary

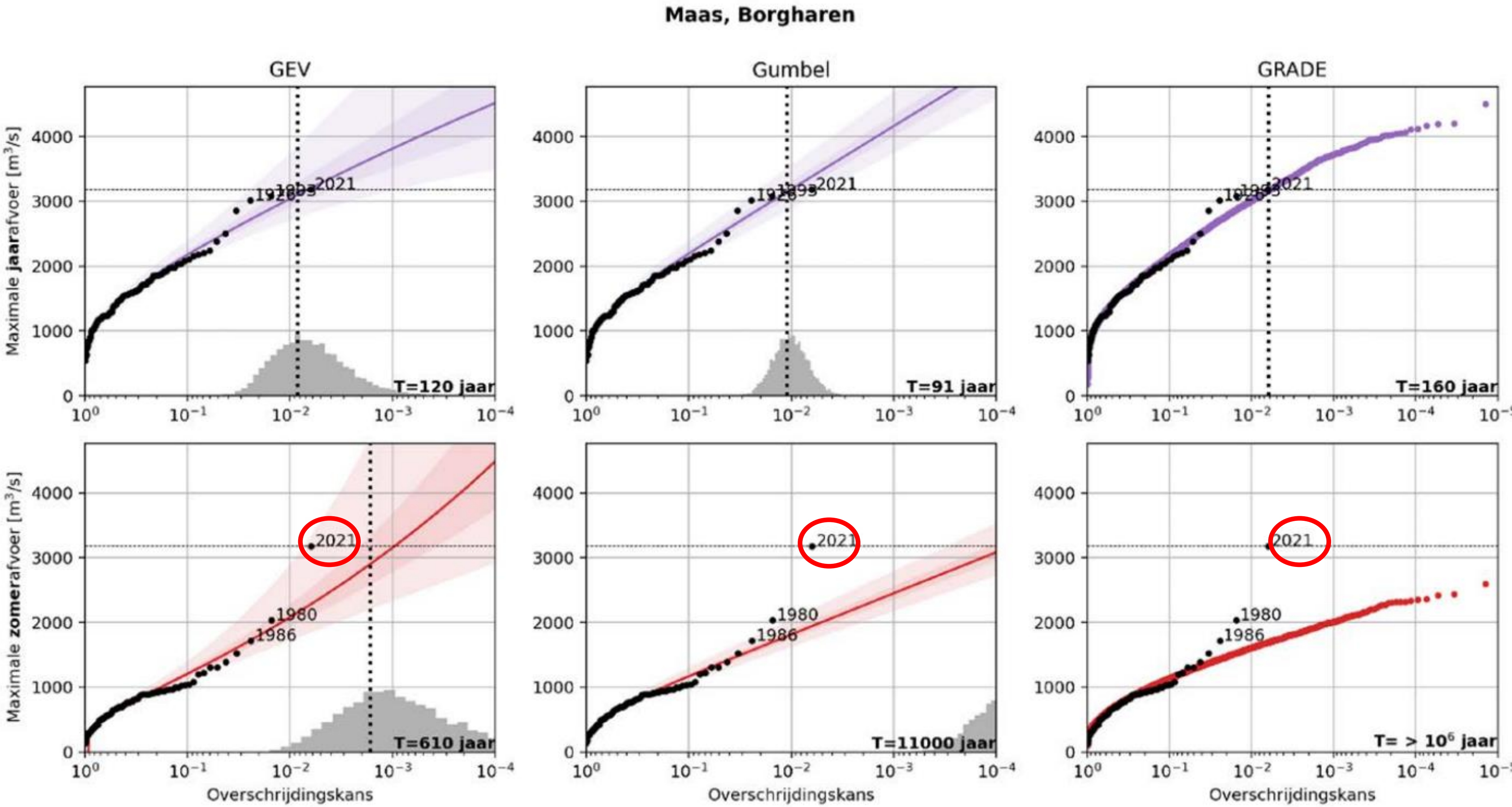
(a) Return period of 100 years



(b) Return period of 1000 years

Figure 3.2: Estimated flood area of Valkenburg for two events with a differ
(Risicokaart, 2019)

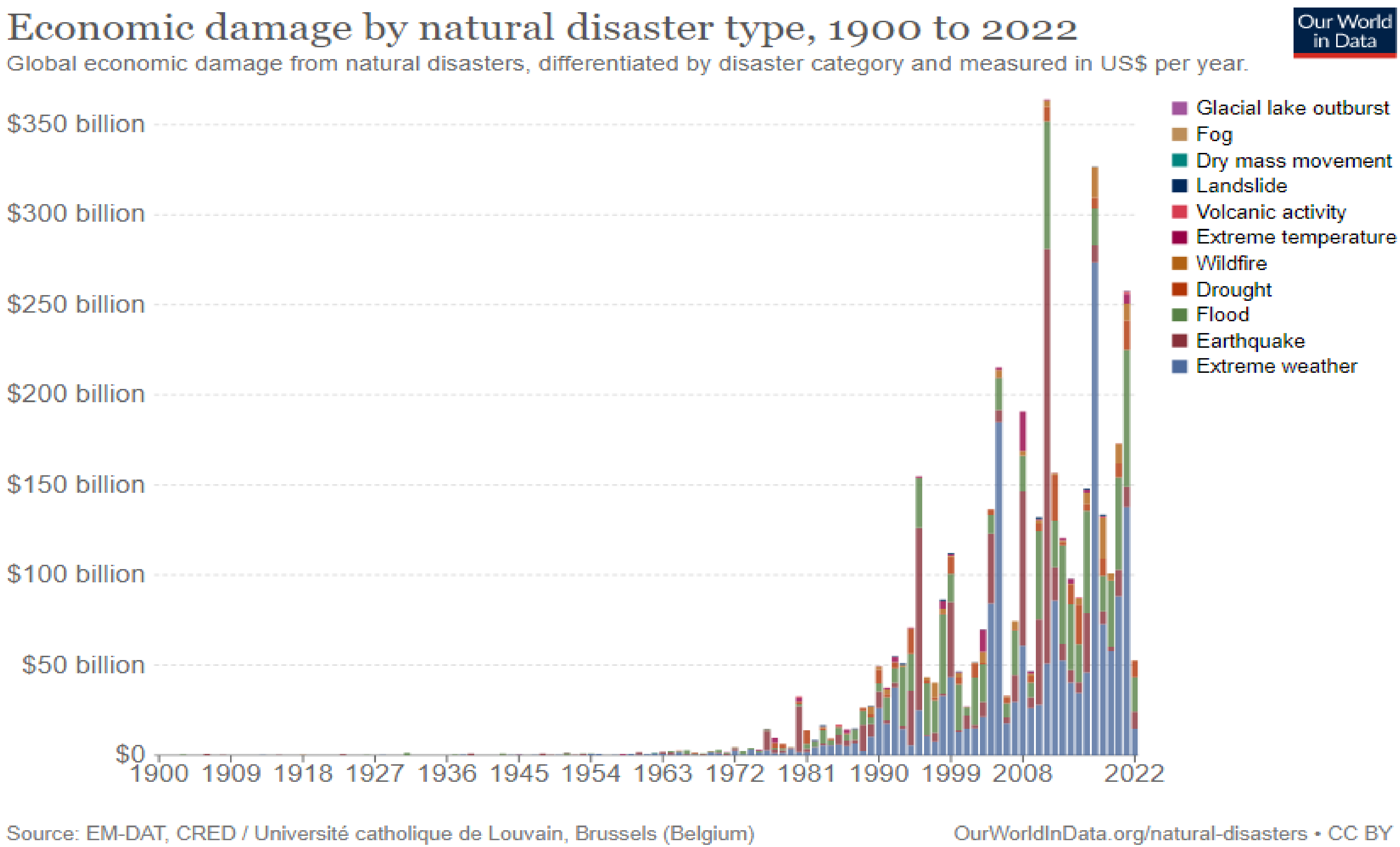
Extreme value analyses Meuse (anual peaks / summer peaks)

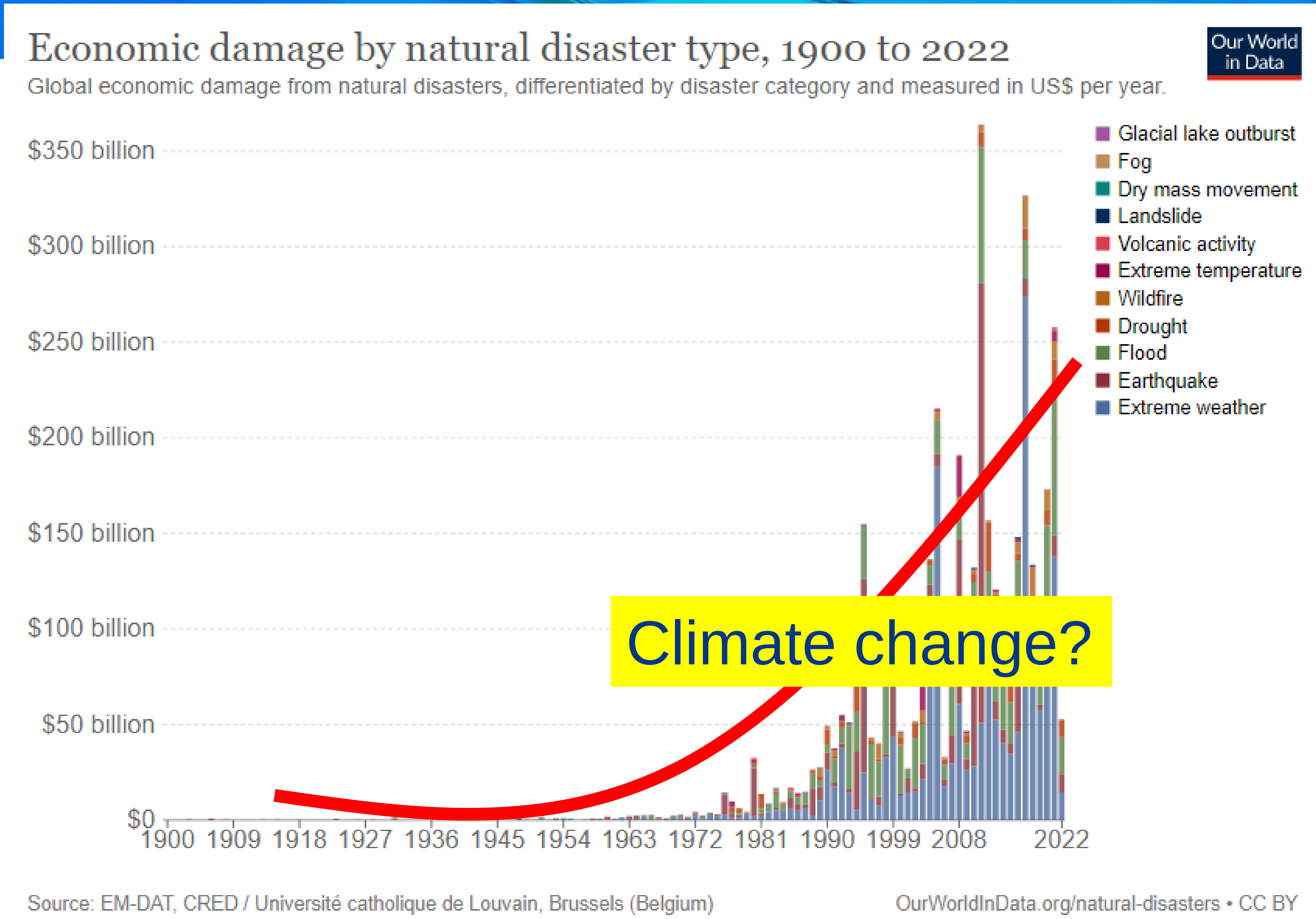


ENW, 2021

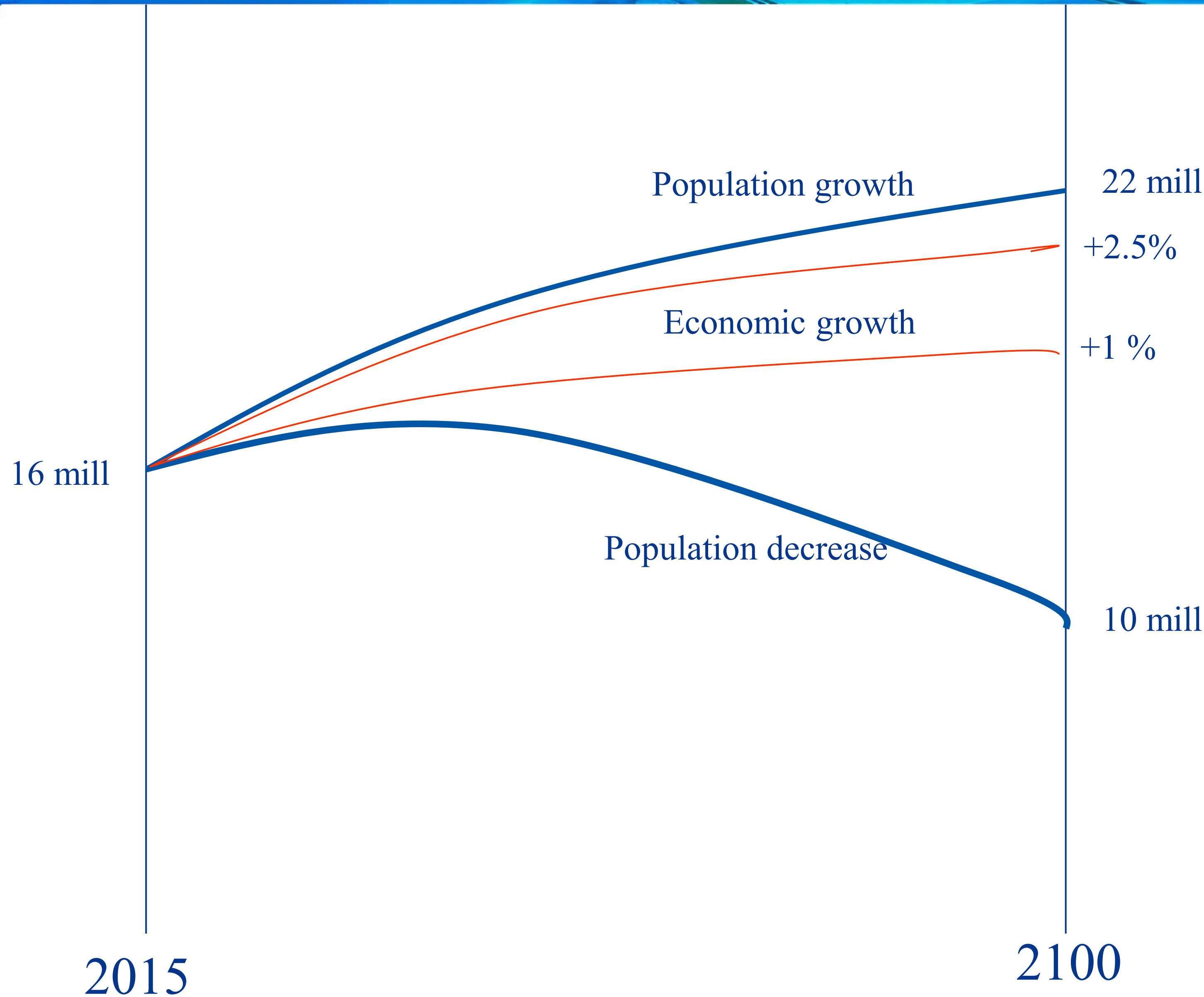
Exposure

Socio economic impacts




Economic damage by natural disaster type, 1900 to 2022
Global economic damage from natural disasters, differentiated by disaster category and measured in US$ per year.
Our World in Data
$350 billion
$300 billion
$250 billion
$200 billion
$150 billion
$100 billion
$50 billion
$0
1900 1909 1918 1927 1936 1945 1954 1963 1972 1981 1990 1999 2008 2022
Glacial lake outburst
Fog
Dry mass movement
Landslide
Volcanic activity
Extreme temperature
Wildfire
Drought
Flood
Earthquake
Extreme weather
Climate change?
Source: EM-DAT, CRED / Université catholique de Louvain, Brussels (Belgium)
OurWorldInData.org/natural-disasters • CC BY

Flood exposure in The Netherlands



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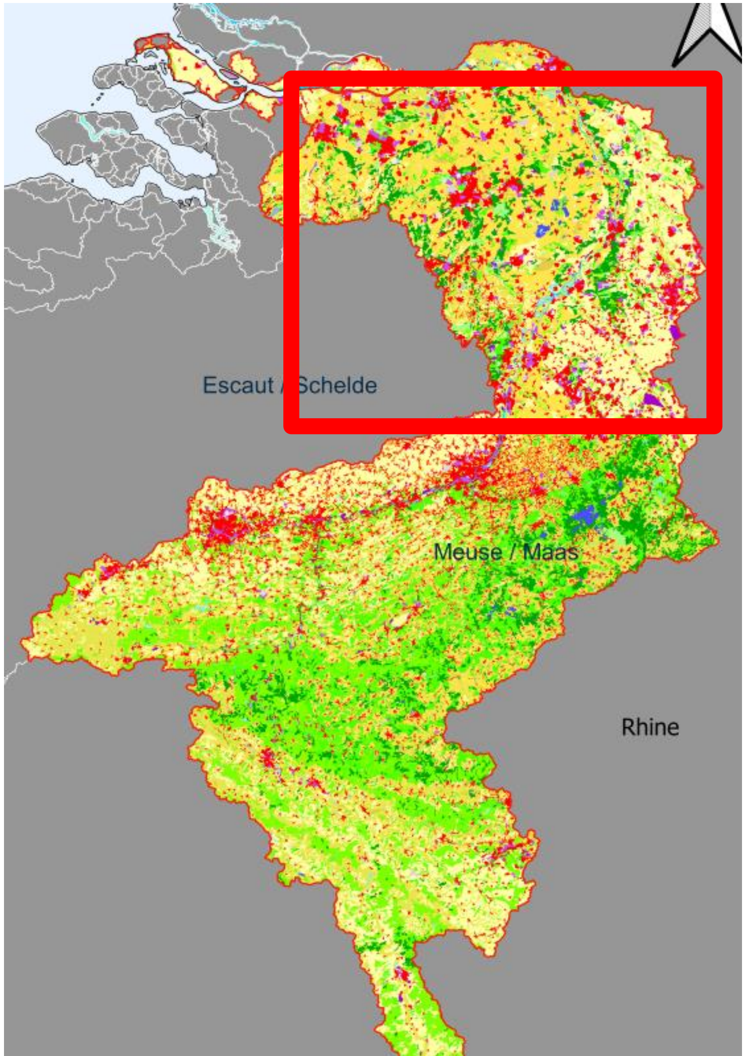
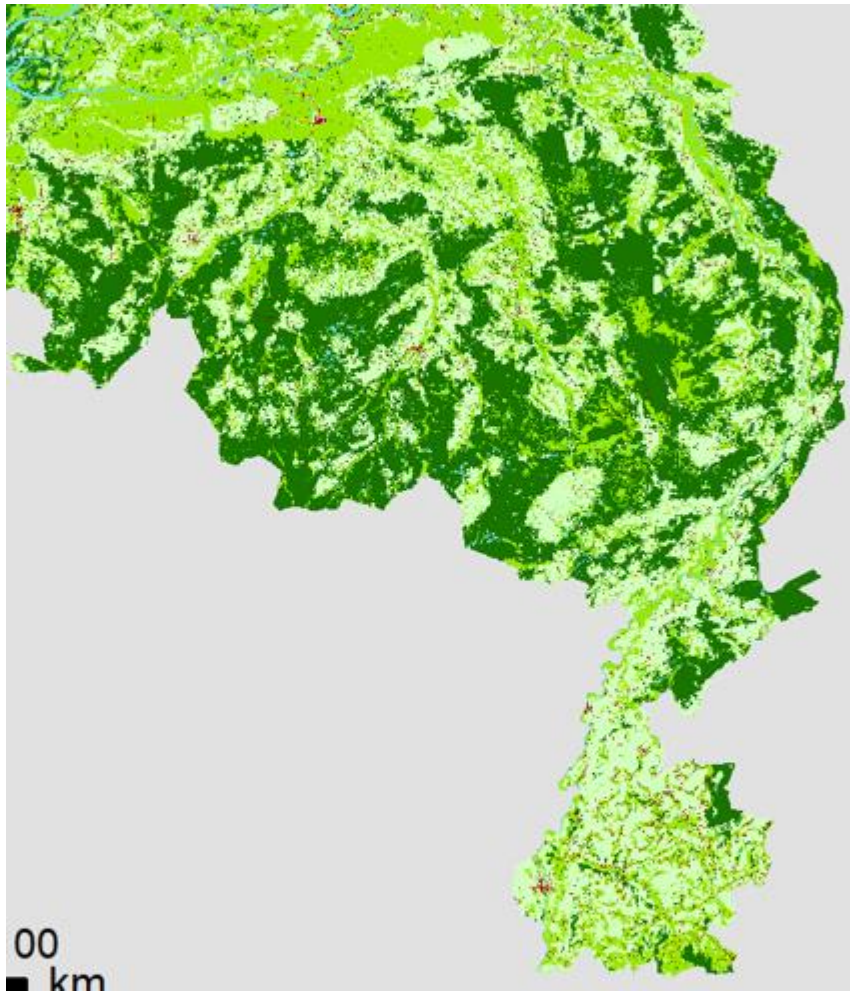
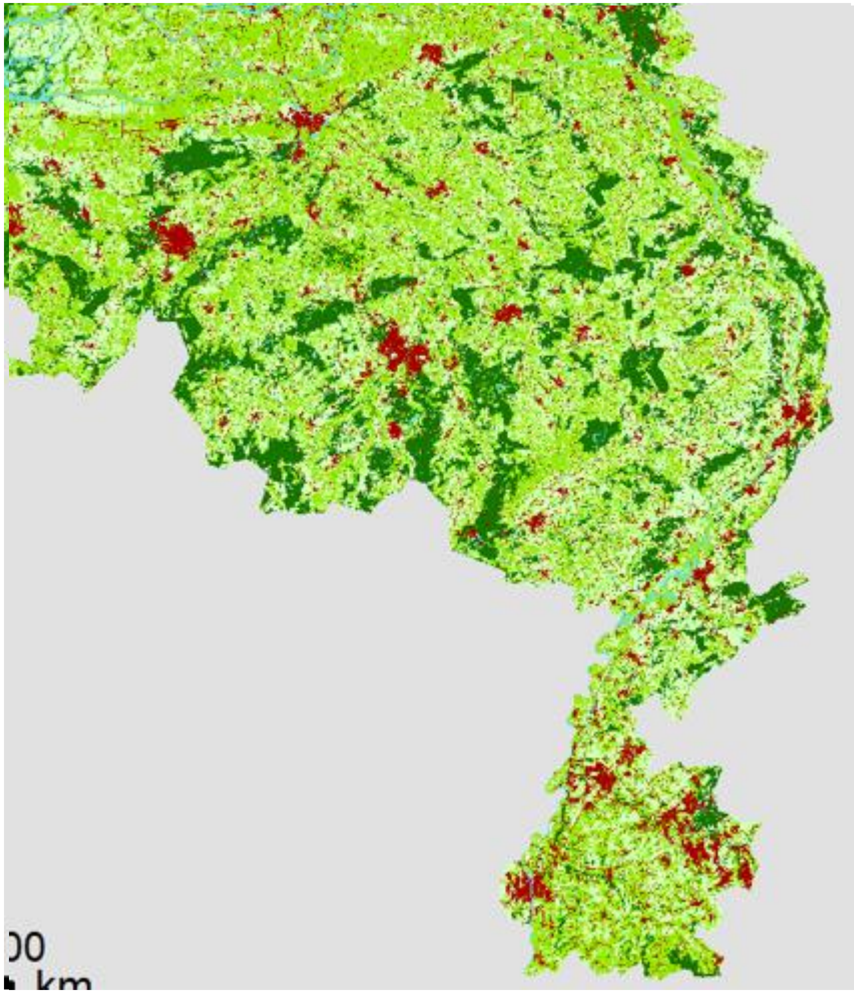
Land use change 1900-2100

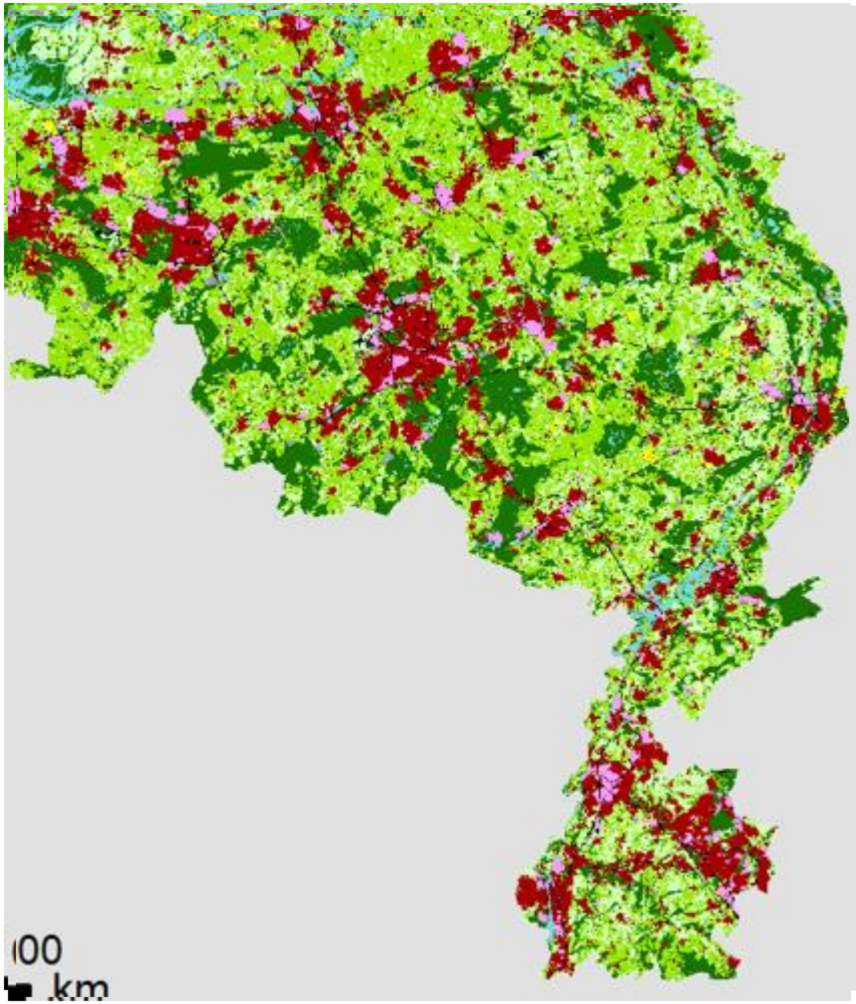




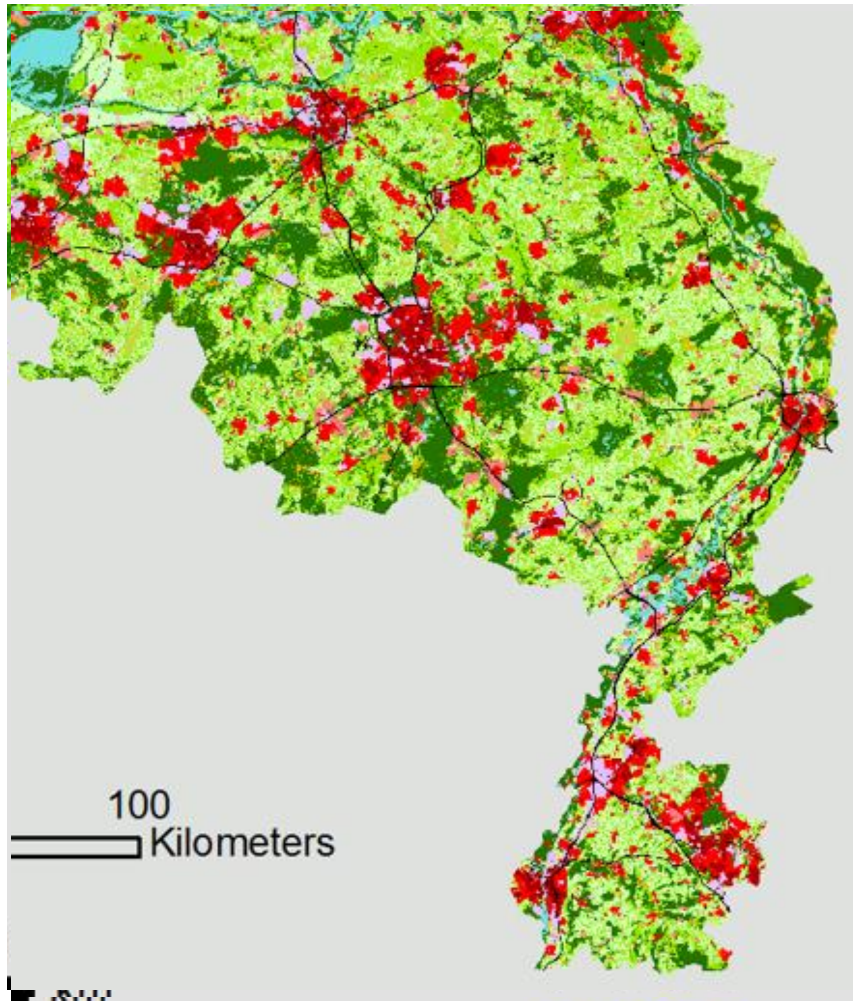
1900



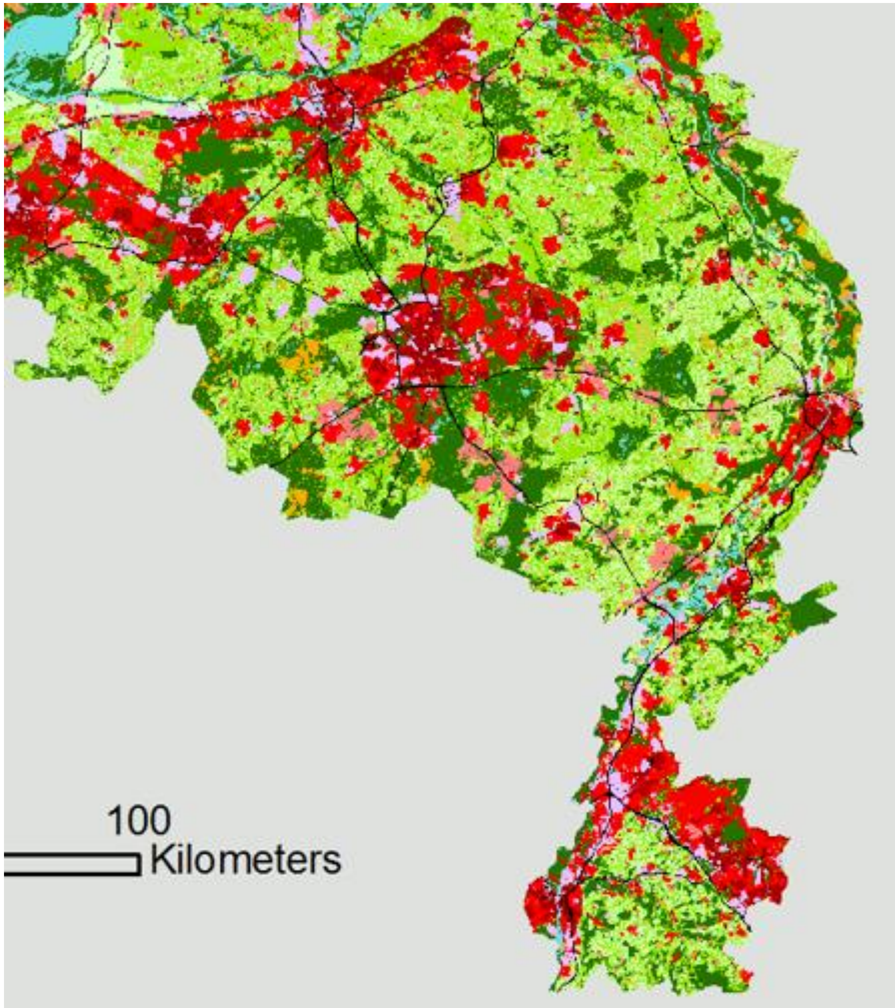
1960



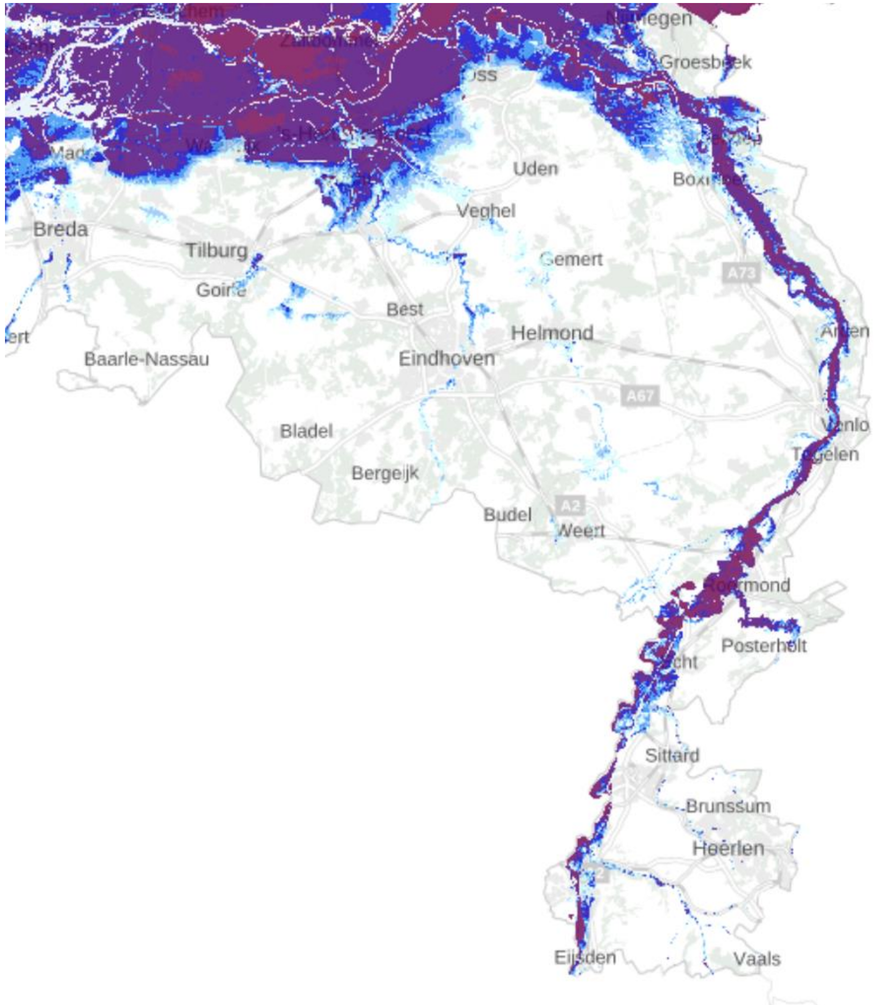
2000



2040

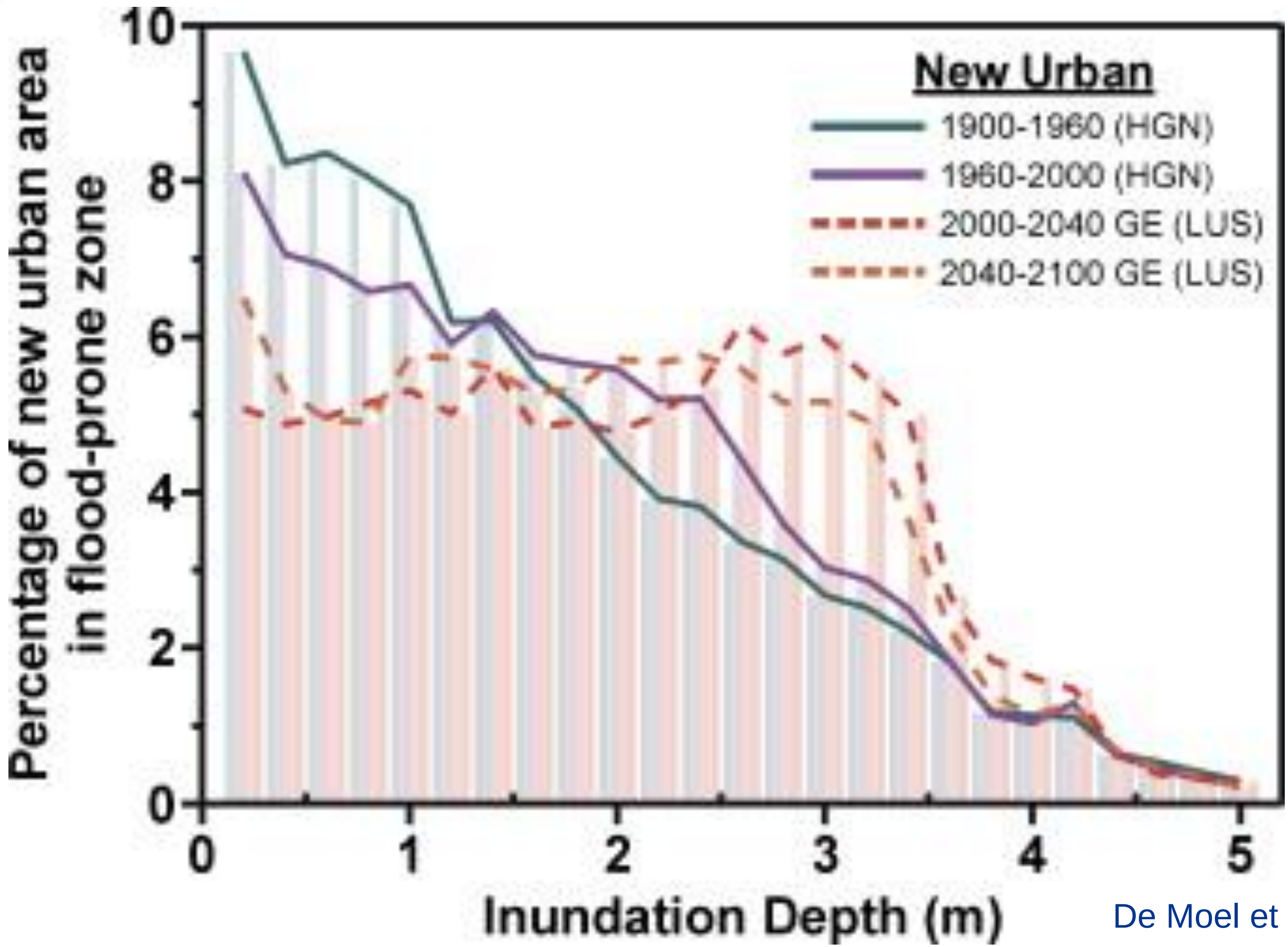


2100


Uden
Veghel
Breda
Tilburg
Gemert
A73
Best
Helmond
Baarle-Nassau
Eindhoven
A67
Bladel
Bergeijk
Budel
A2
Weert
Posterholt
Sittard
Brunssum
Heerlen
Eijsden
Vaals

2100

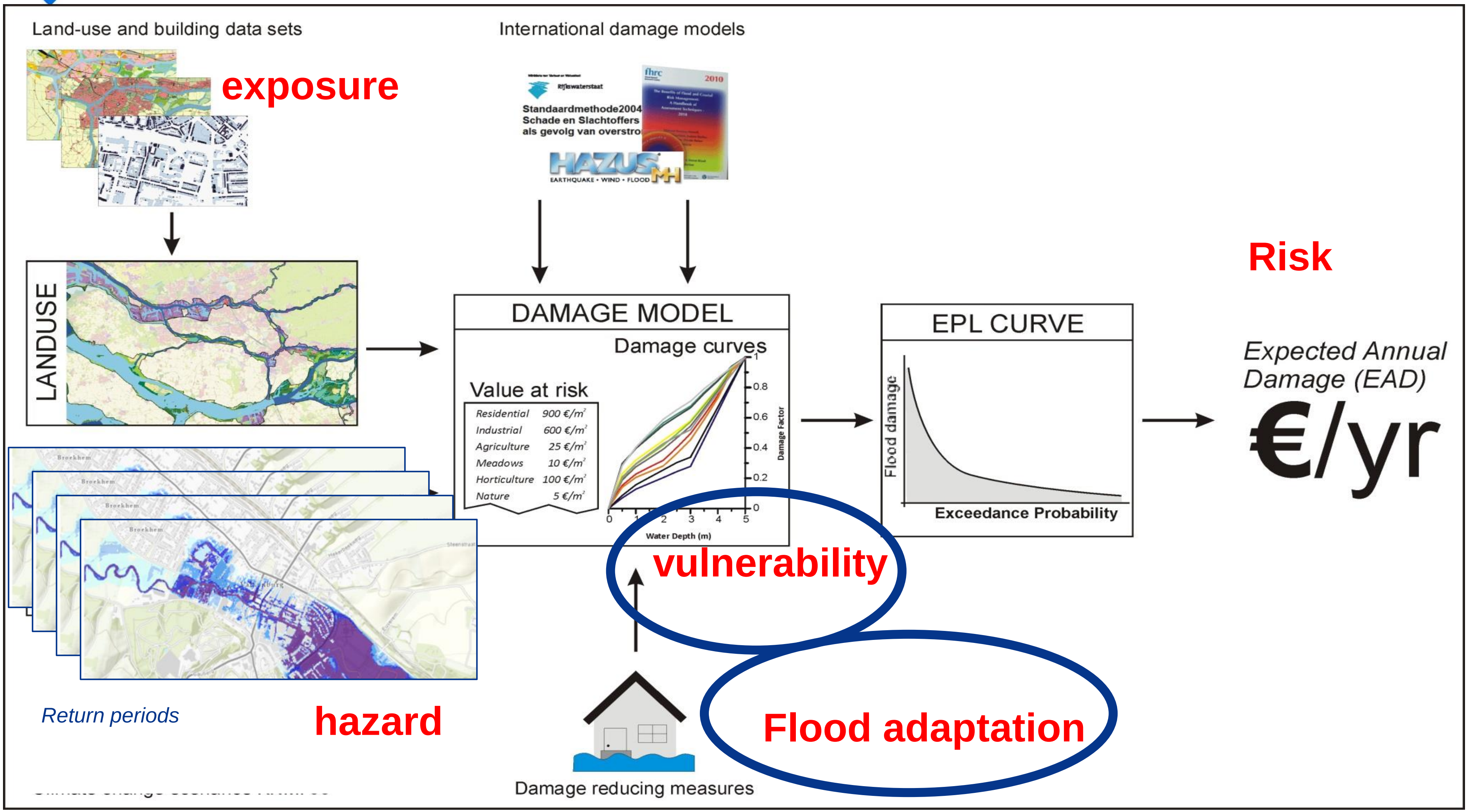
Levee effect, The Netherlands



De Moel et al., 2012

Overlay Flood map with exposed assets and people

Flood risk assessment



De Moel et al., 2013

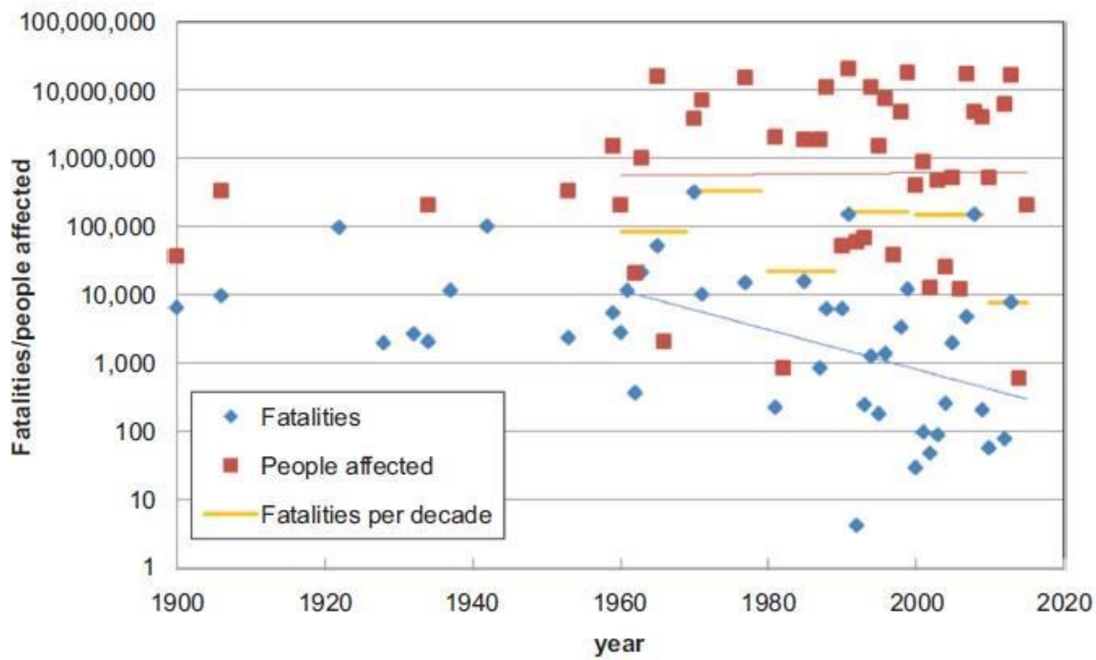
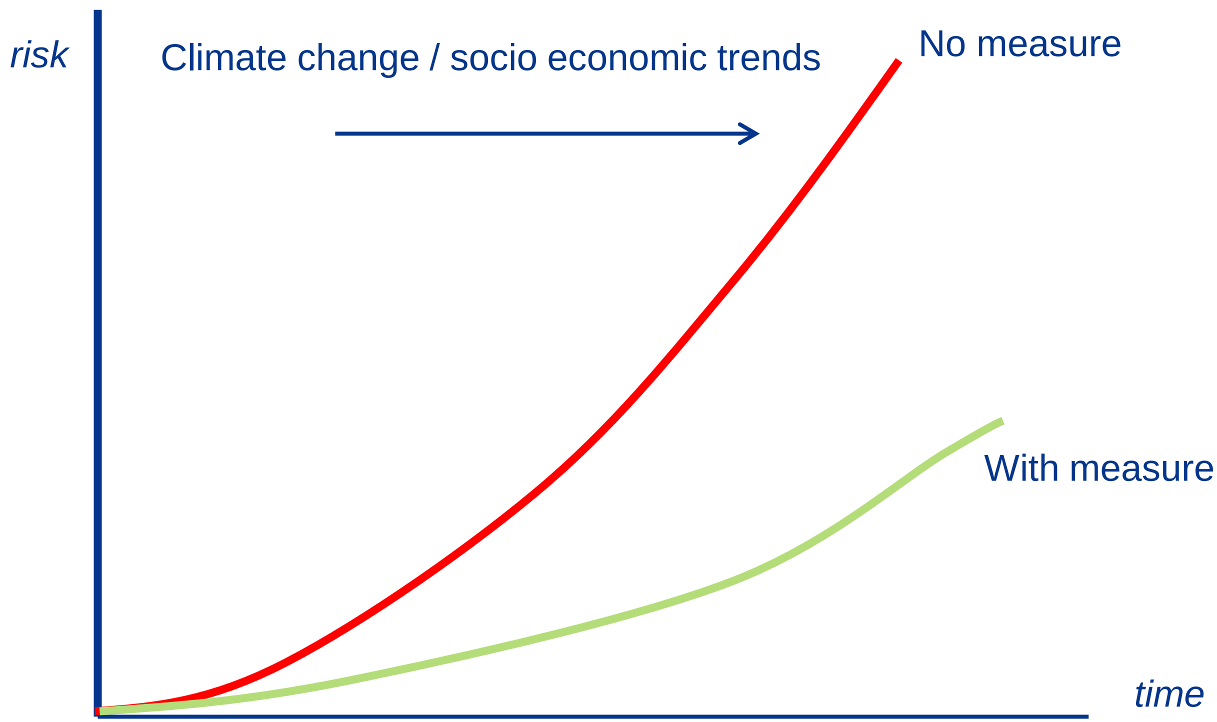


Figure 1. Global total annual fatalities and population affected from coastal storm surges 1900–2015, including exponential trend lines since 1960.

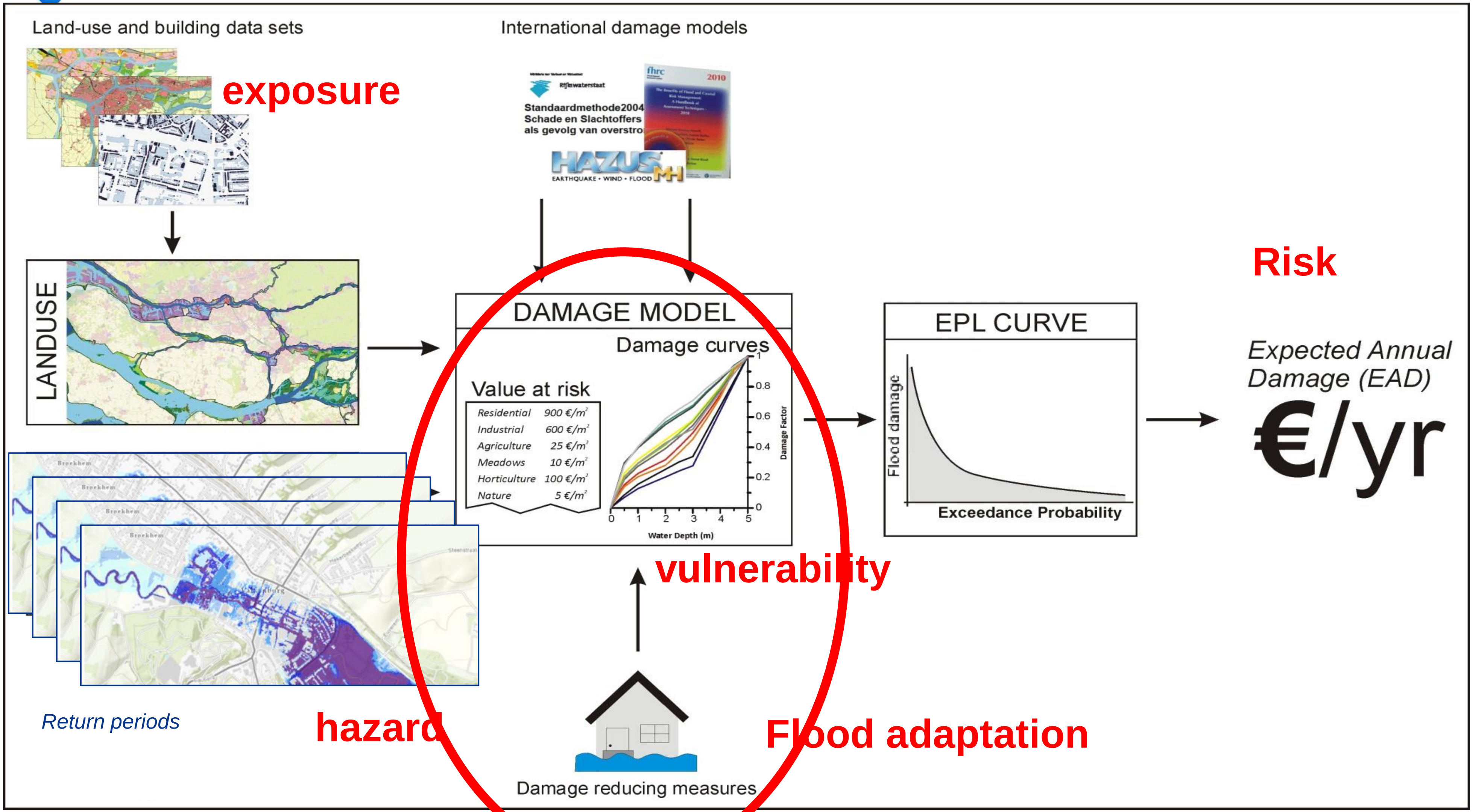
Bouwer and Jonkman. 2018, ERL

Risk / Static scenario based approach



Aerts et al. 2018; Nature cc

Dynamics in vulnerability and adaptation

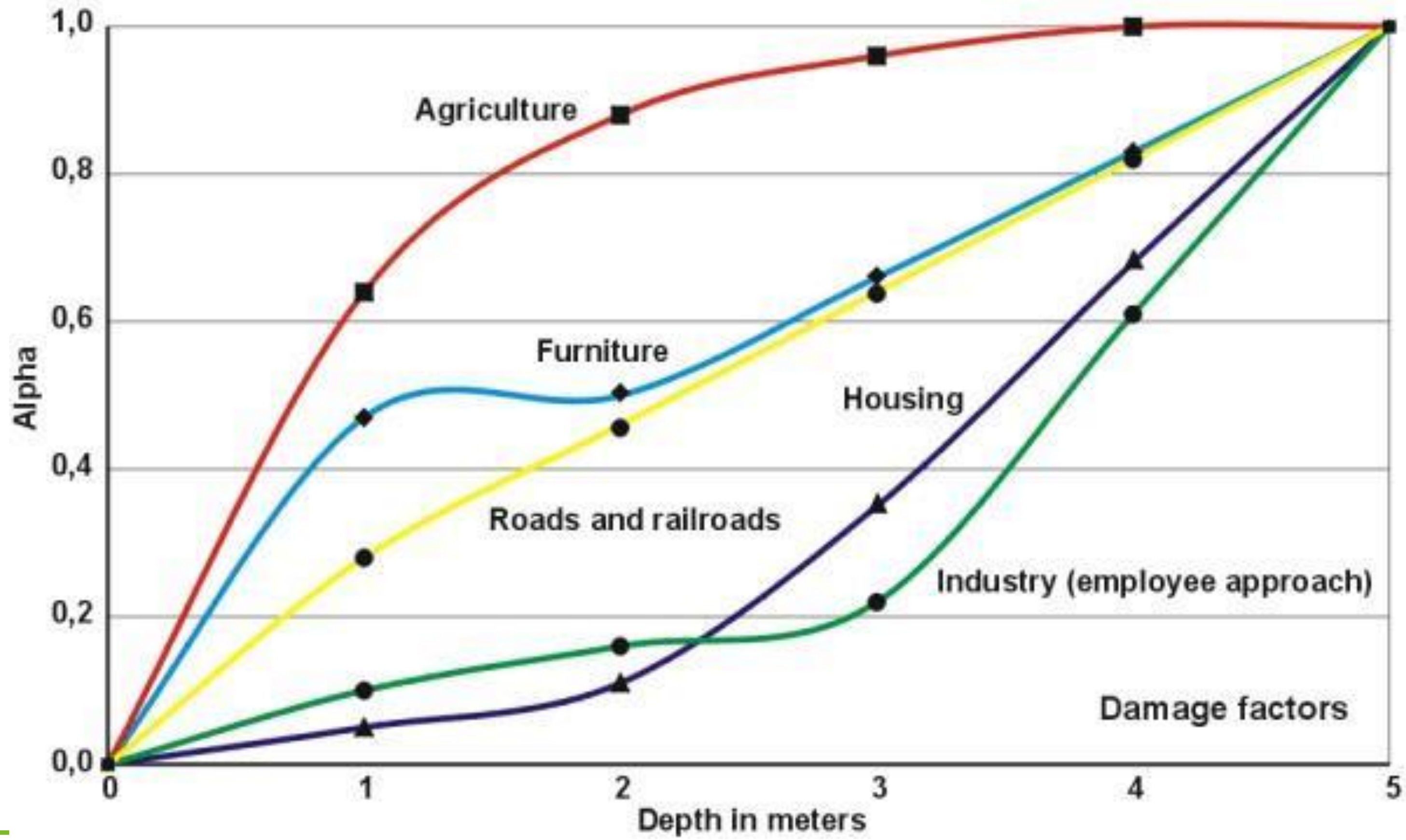


De Moel et al., 2013


SANDYBANK
FLOODGATE

vulnerability model: depth-damage curves

% damage from total



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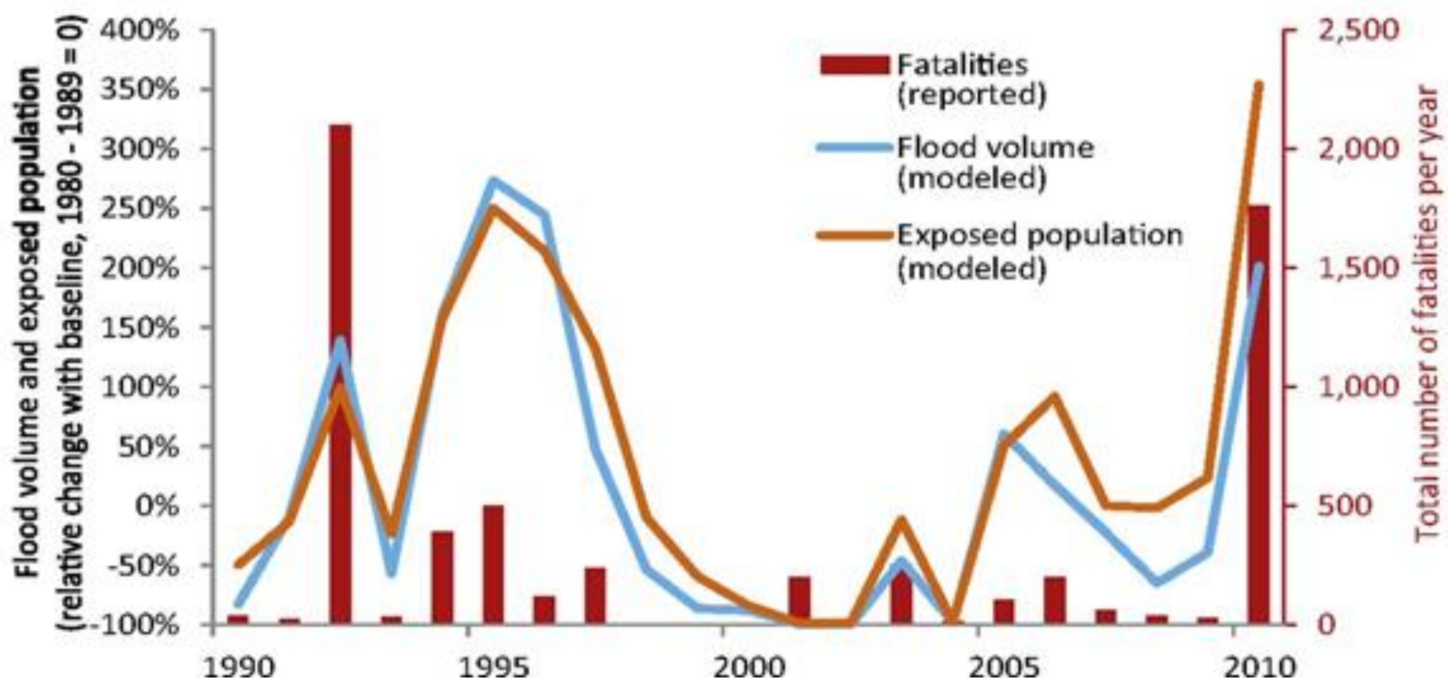
Pakistan floods; 2010, 2022

Pakistan floods 1990-2010



Jongman et al. 2015, PNAS

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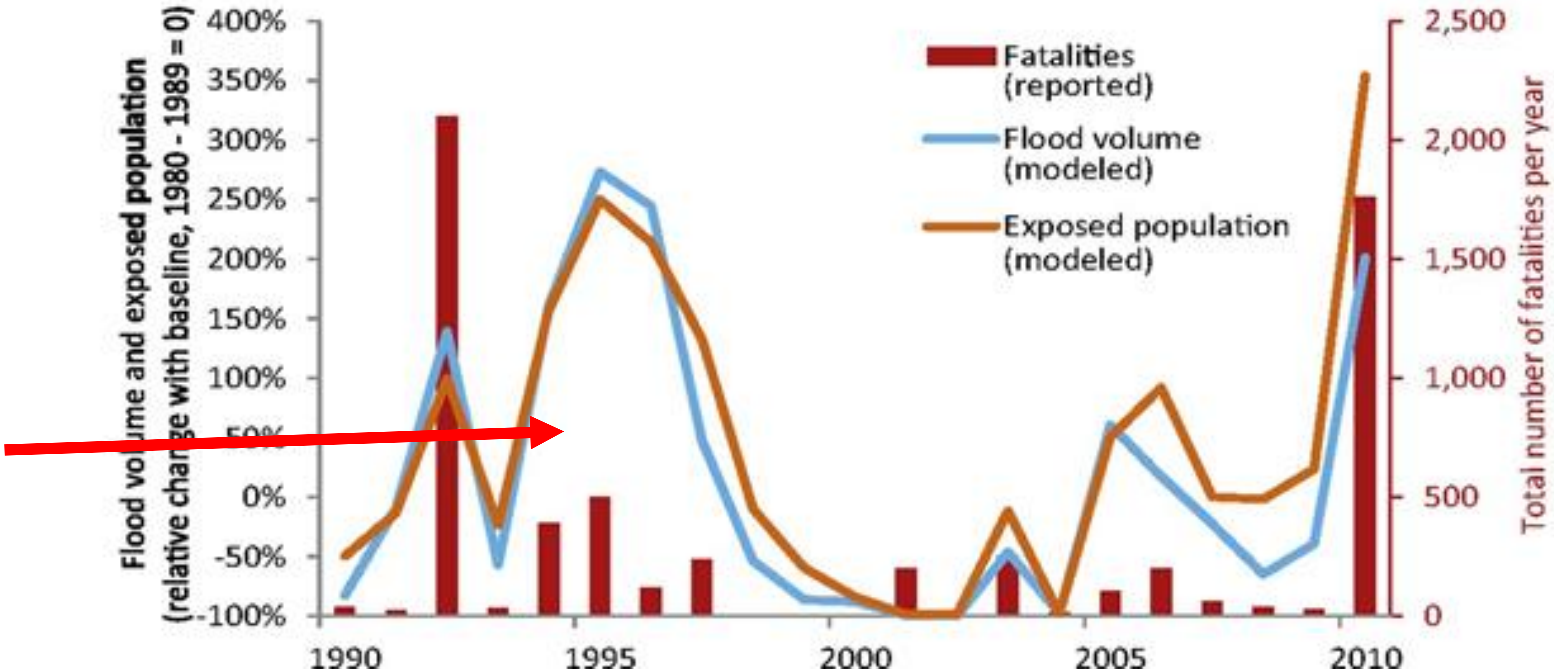
People relocated?

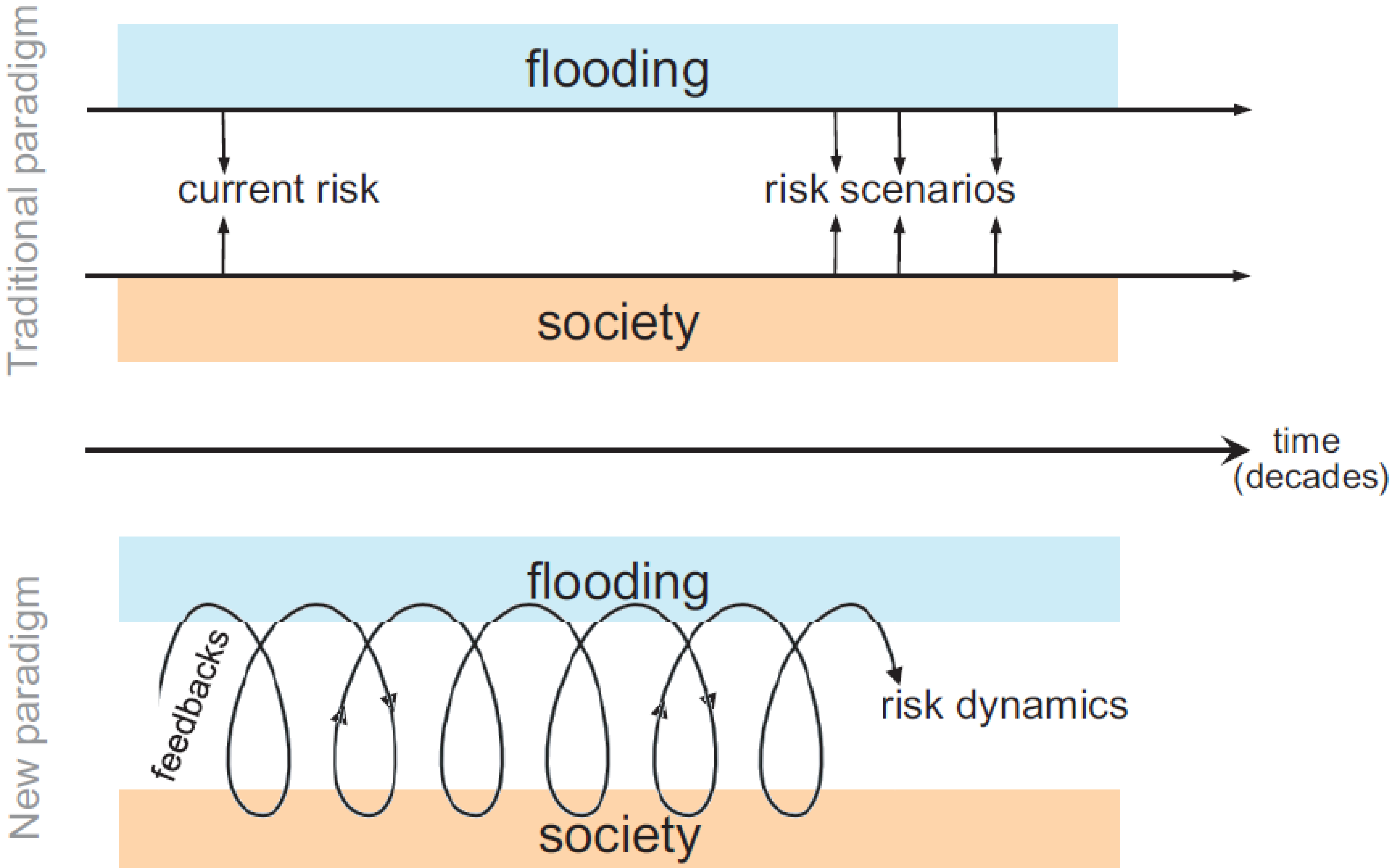
Better measures?

Destructed houses were not rebuild?



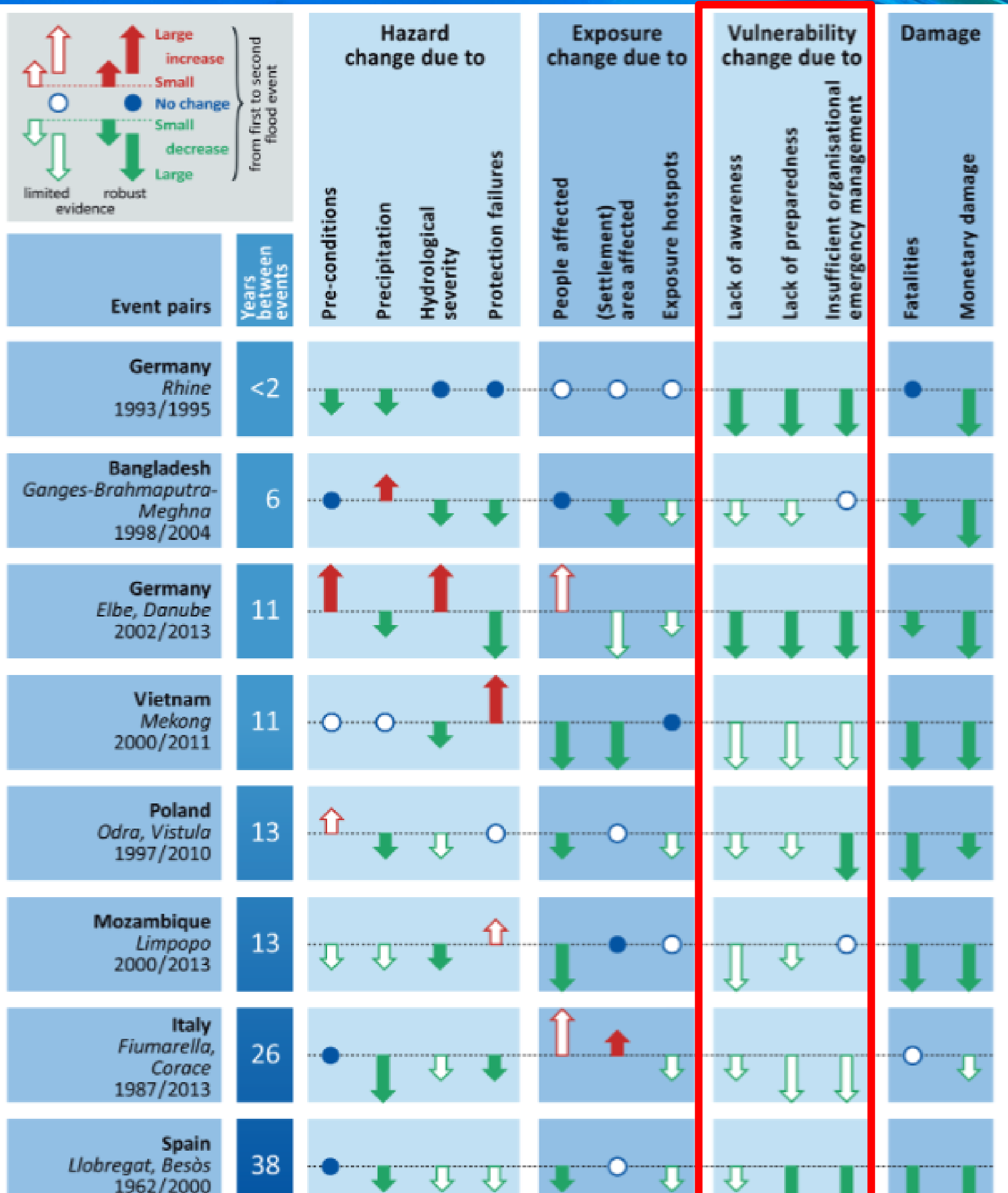
Jongman et al. 2015, PNAS

Socio Hydrology



Di Baldessarre et al., 2015; WRR

Adaptation effect through consecutive events



Kreibich et al., 2017; 2022

WATER RESOURCES RESEARCH, VOL. 35, NO. 11, PAGES 3459–3465, NOVEMBER 1999

Analysis of flood damages from the 1993 and 1995 Meuse floods

H. G. Wind, T. M. Nierop, C. J. de Blois, and J. L. de Kok

Faculty of Technology and Management, Department of Civil Engineering, University of Twente
Enschede, Netherlands

Table 1. Damage Data of the 1993 and the 1995 Meuse Floods

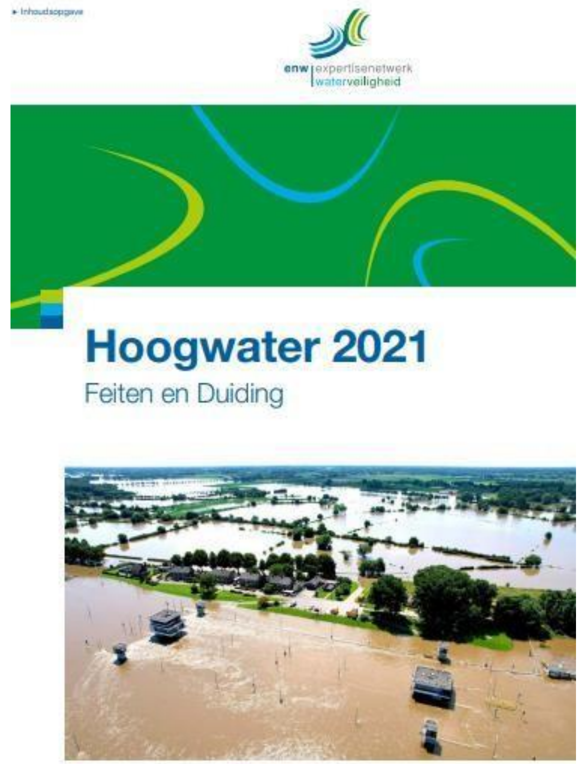
Damage Category	1993 Damage, Millions of Dfl	Percent	1995 Damage, Millions of Dfl	Percent
Private	96.5	38	40.7	25
Houses	80.8		40.0	
Cars	1.0		*	
Caravans	13.5		0.7†	
Gardens	1.2		*	
Agriculture and horticulture	19.4	8	20.9	13
Trade and industry	74.0	29	62.2	38
Trade and industry	71.3		62.2	
Gravel extraction	2.7		*	
Institutions	2.6	1	2.1	1
Government	61.3	24	39.1	24
Buildings and sites	6.6		0.5	
River infrastructure	21.9		1.5	
Land infrastructure	15.5		18.0	
Public utilities	7.3		*	
Clear away and assistance	10.0		19.1	
Total	253.8	100	165.0	100

*Data not available.
†Only holiday houses.

estimating the number and type of flooded objects. However, whether all the objects in the flooded area are indeed likely to experience damage and result in flood damage reports depends on individual precautionary measures and on the attitude and experience of the public and authorities with previous floods. This introduces an additional margin of uncertainty in the number of flood damage reports, which, as shown in section 4.1, can be 20% or more.

Social sciences: surveys and statistical methods

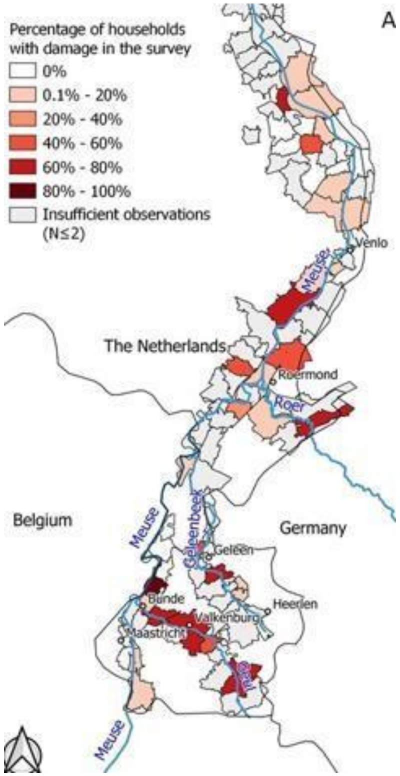
2021 floods Central Europe



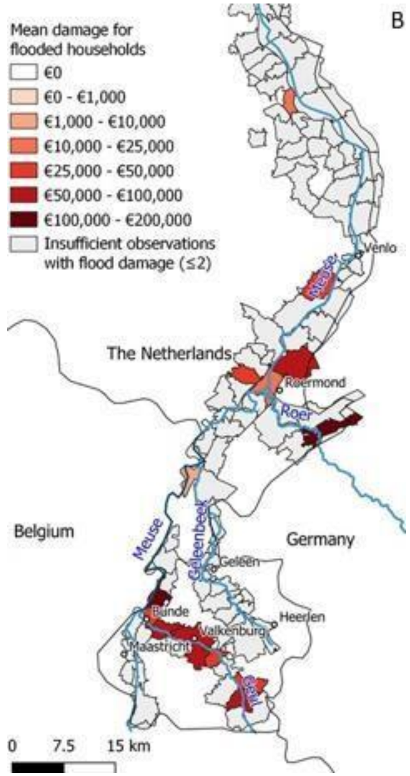
Key results

- 2500 households and 600 firms experienced flood damage
- Total economic damage estimated between €350 million and € 0 million

Experienced Flood Damage



% with damage

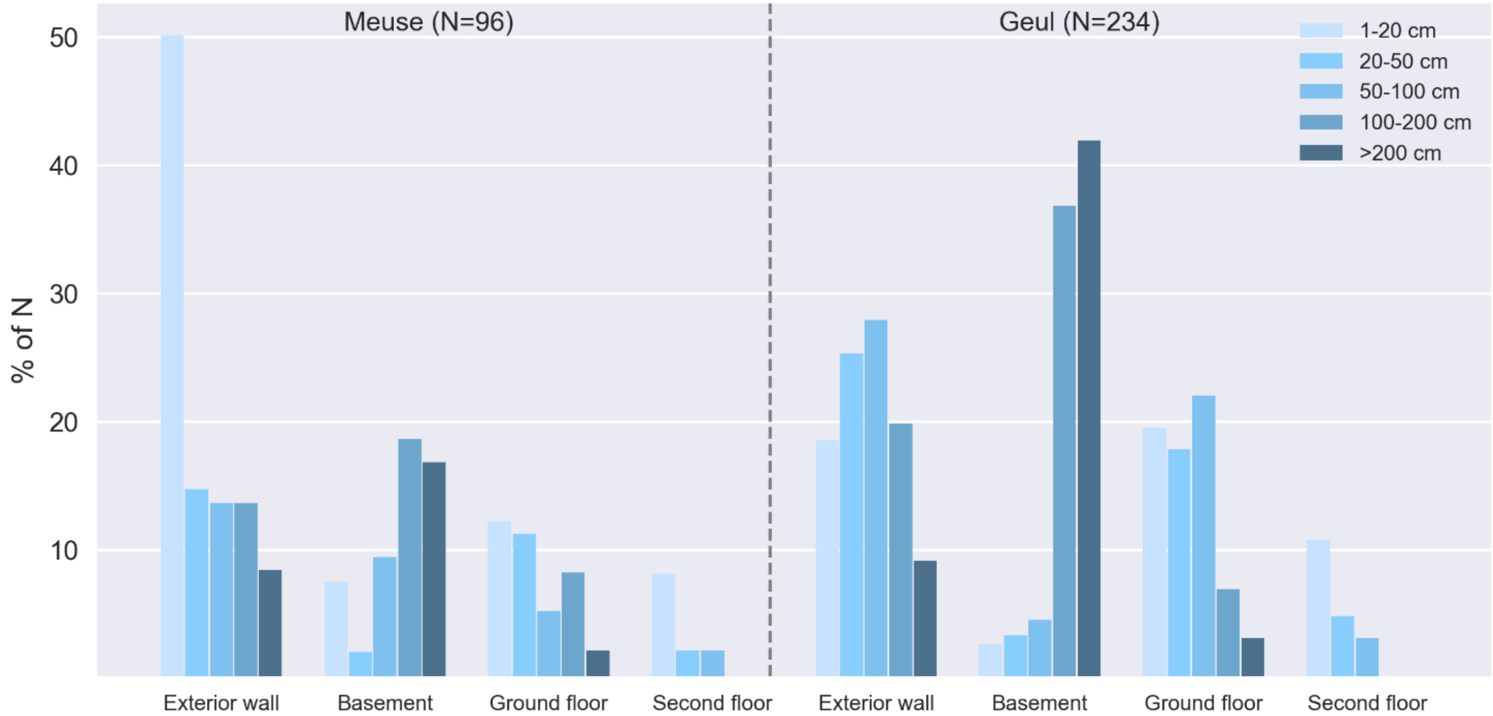


Mean damage

Median damage flooded households:

- Building €25,000
- Floor €8,000
- Household contents €17,000
- Cleaning costs €2,500

Water Levels for Flooded Households



- In total 27% of respondents experienced water in their home

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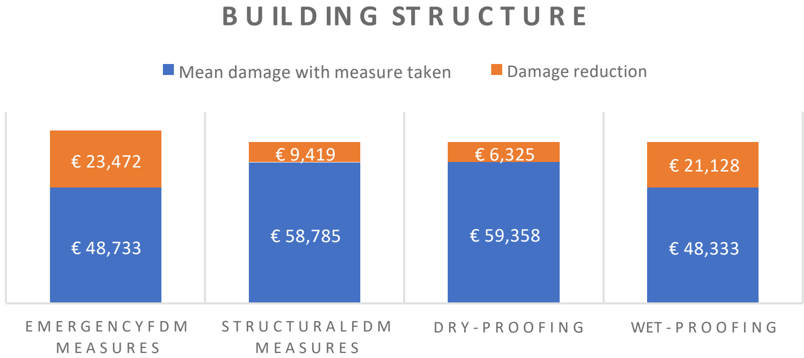
Goal: determine flood vulnerability while accounting for private adaptation actions

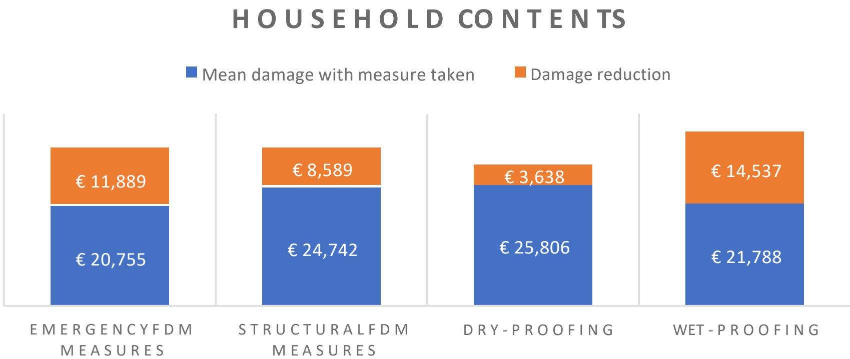
Flood Risk Reduction Measures of Flooded Households

Measure	% of respondents with measure
Placing sandbags	35%
Elevating possessions	34%
Installing a water pump	32%
Installing a water-resistant floor	25%
Elevating electrics	20%
Placing shields or beams	16%
Elevating floor or entrance	10%
Using other water-resistant material	10%
Building water-resistant walls	9%
Strengthening foundations	4%

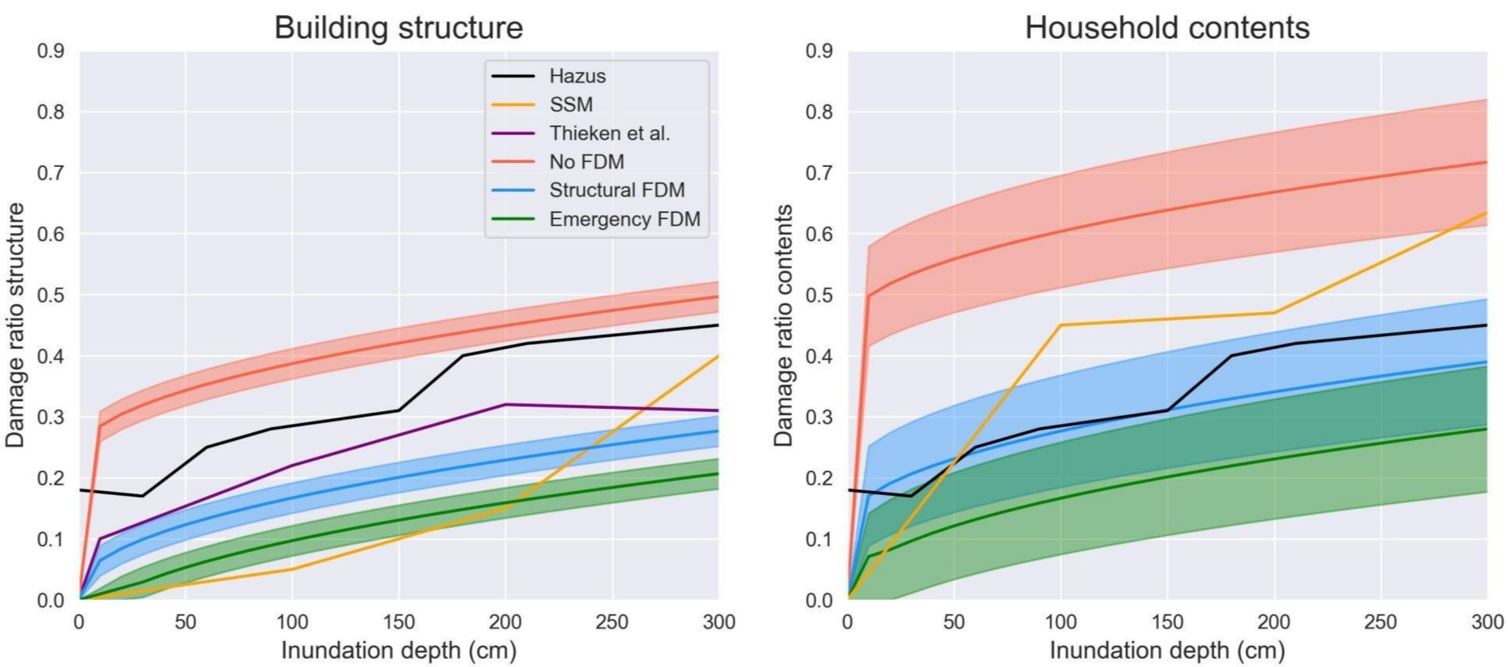
Effectiveness of Flood Damage Mitigation Measures



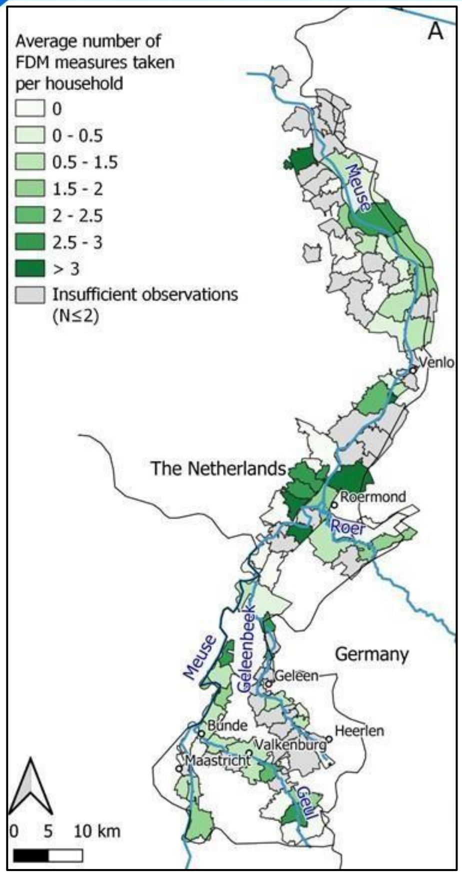
- Reduction in damage ratios:
  - Building structure: 0.20 – 0.29
  - Household contents: 0.37 – 0.54

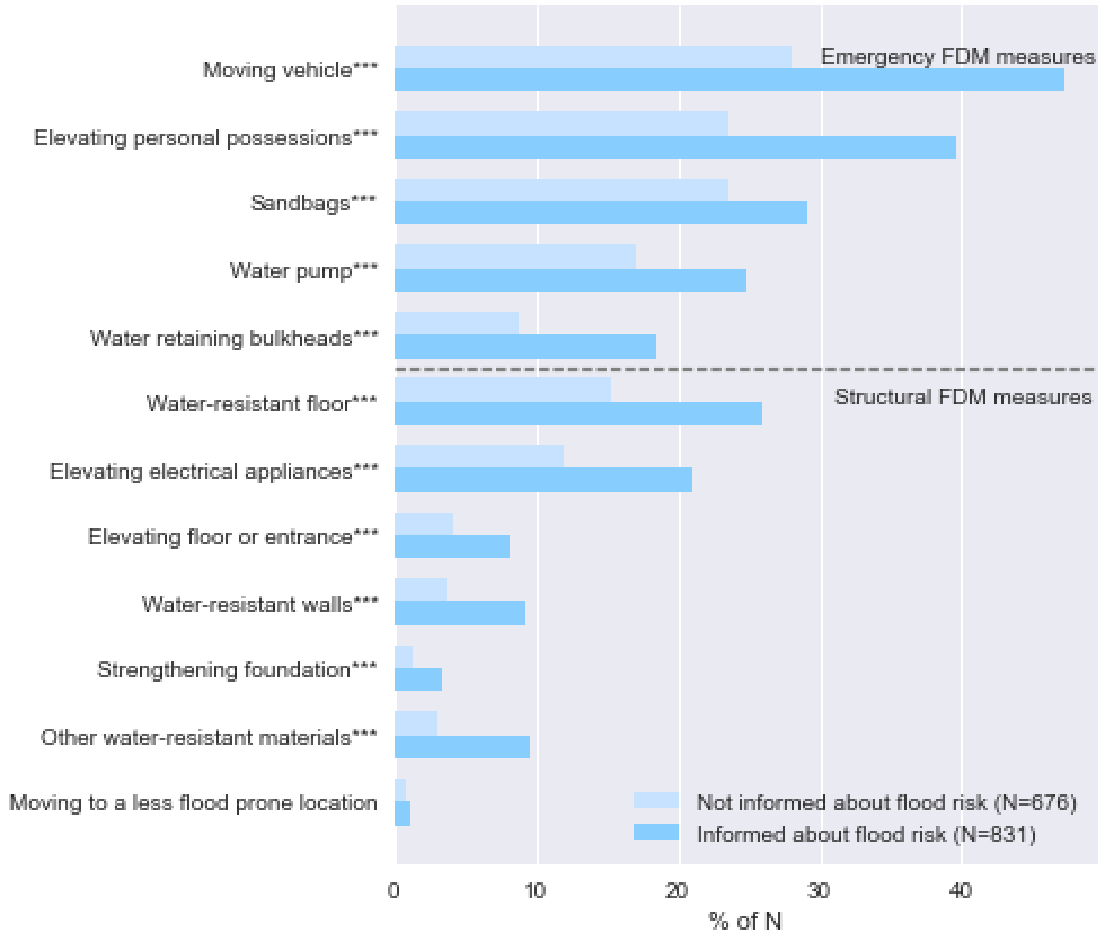


Outcome: building vulnerability estimates that can be adjusted for private adaptation actions



Influence of “risk awareness” on adaptation actions





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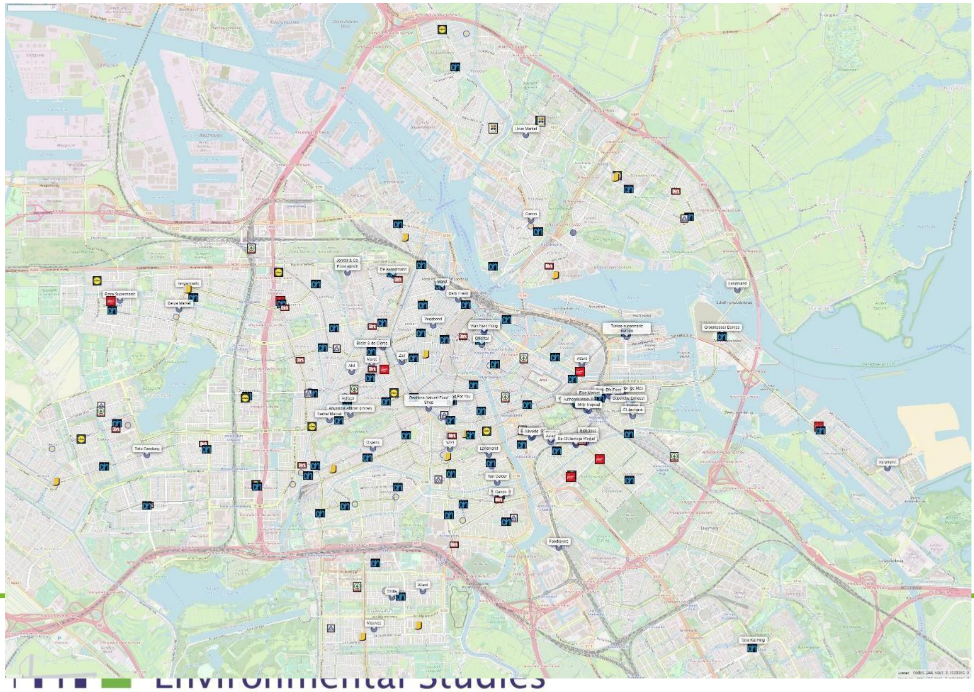
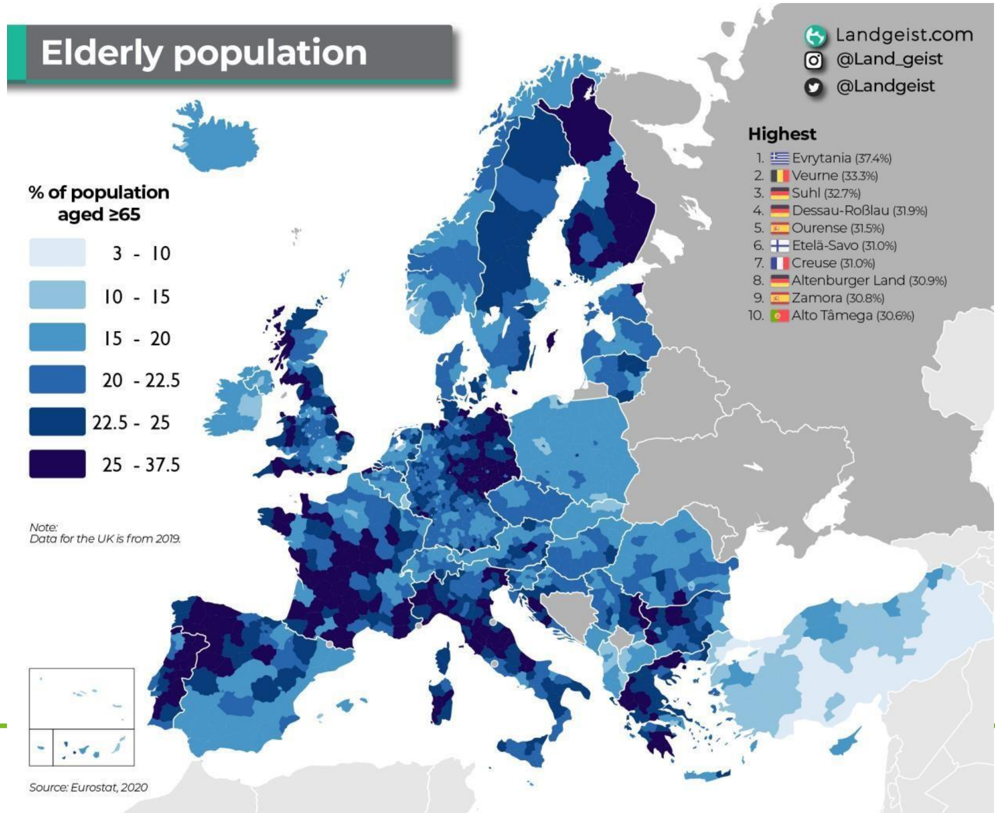
Socio Economic data

Distance to health facilities





Modeling adaptation dynamics

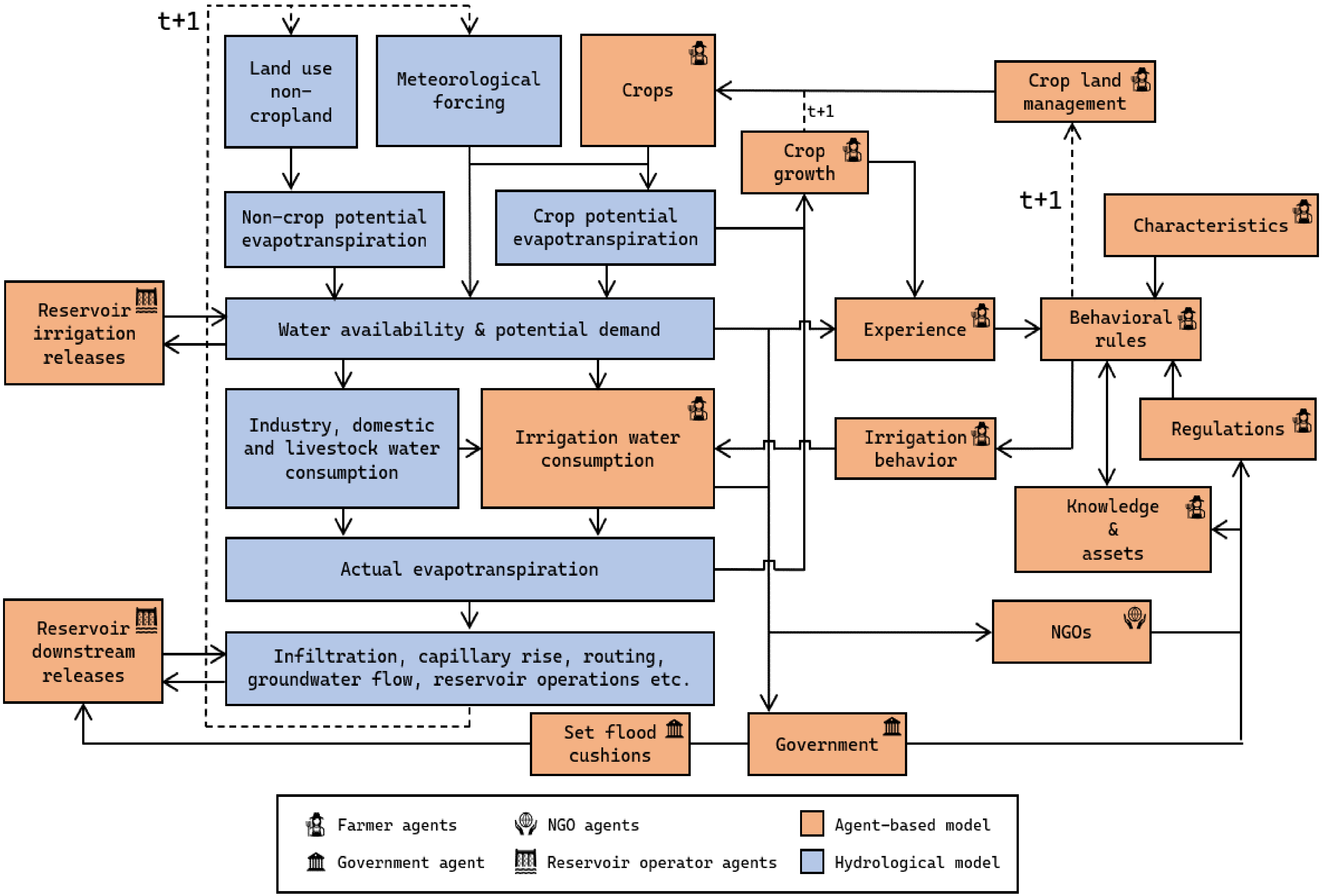
Who is interacting with the hydrological system?

Enable simulating behavior of main three agents in FRM:

- Government
- Households
- Private Sector (e.g. Insurance)

Flowchart of the GEB model (applied for droughts)

The hydrological system affects the people (orange), and the people affect the hydrological system (blue)



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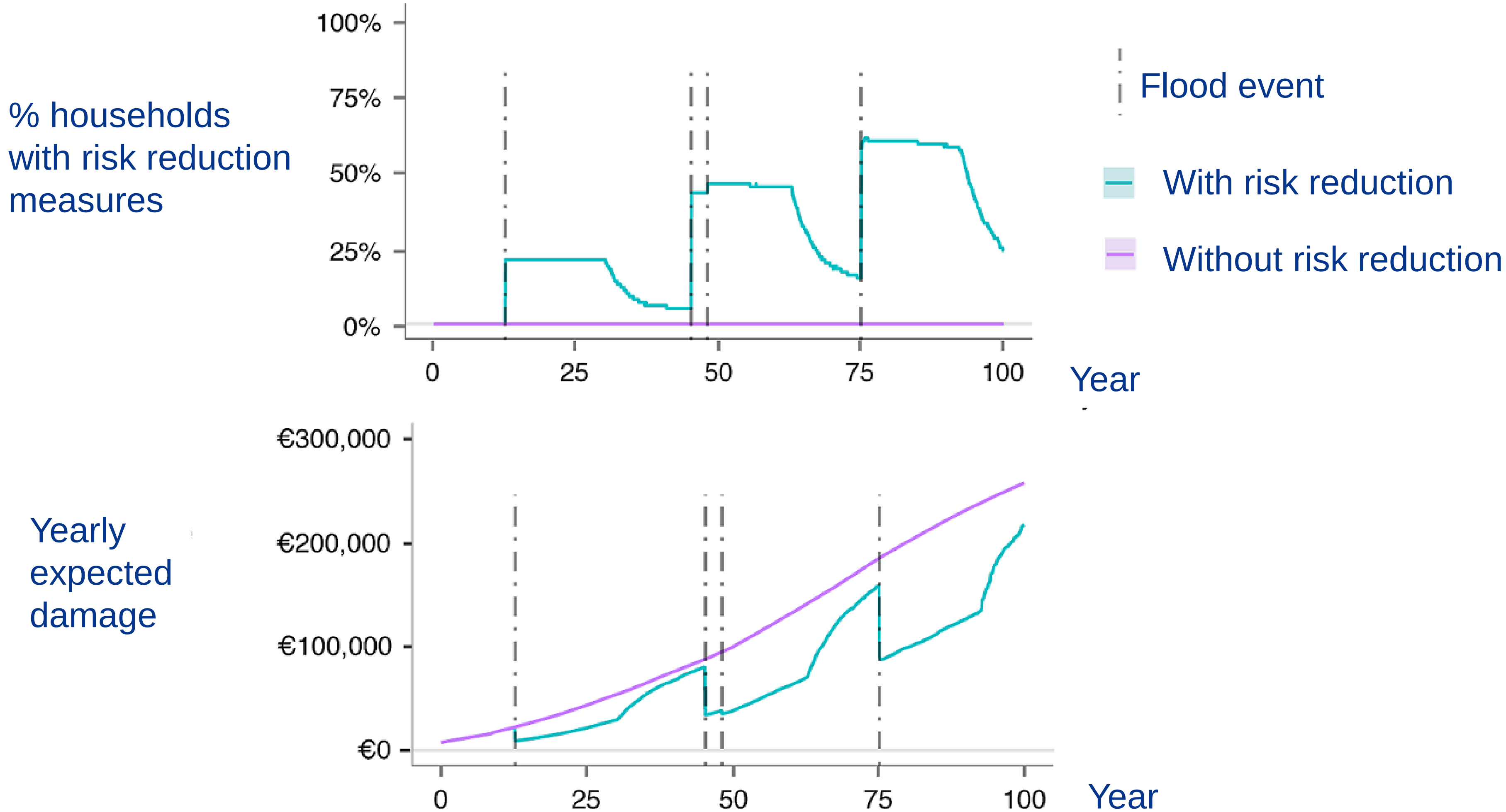
Flood risk / ABM model Rotterdam



Source: Haer, Botzen, de Moel, Aerts (2017), *Risk Analysis*

JCAR-ATRACE

Joint Cooperation programme for Applied scientific Research

2023-2028

Accelerate Transboundary Regional Adaptation to Climate Extremes

Joint structural policy-relevant research on flood and drought risk management in regional river basins

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Overall program management: Dr.ir. Kymo Slager kymo.slager@deltares.nl

Main objectives

Objective 1: Preparing for Future Water Challenges

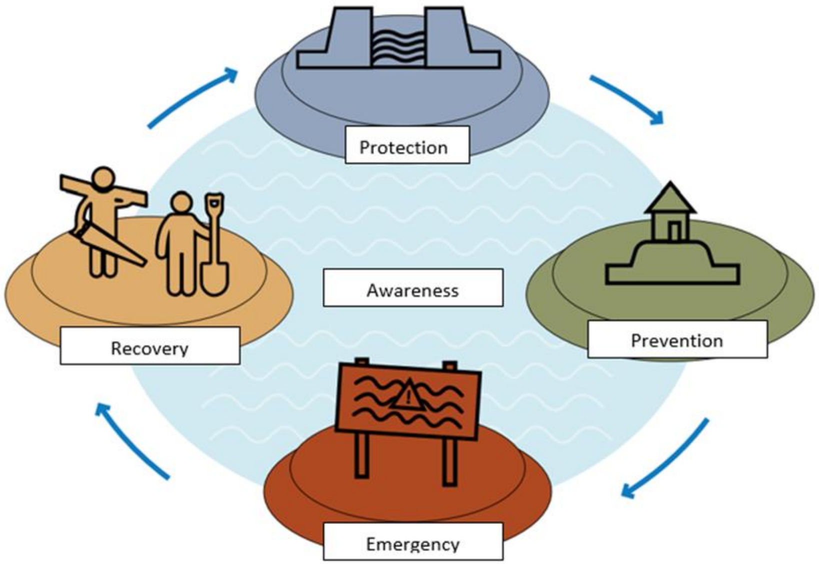
- Facilitate European regional governments on transboundary flood and drought risk management of smaller regional river basins;

- Enhance integrated planning, development and management.

Objective 2: Knowledge cooperation

- Support the development of an international expert community on flood and drought risks in regional river basins;

- Fostering long-term partnerships between European knowledge institutes and enhance the knowledge base to inform strategies on mitigation and adaptation



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Haer, T., Botzen, W., Aerts, J.2016. The effectiveness of flood risk communication strategies and the influence of social networks: insights from an agent-based model. *Environmental Science and Policy*, 60: 44-52.

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Winsemius et al. 2016. Global drivers of future flood risk. *Nature Climate Change*, 6: 381-385.

Thanks for your attention!

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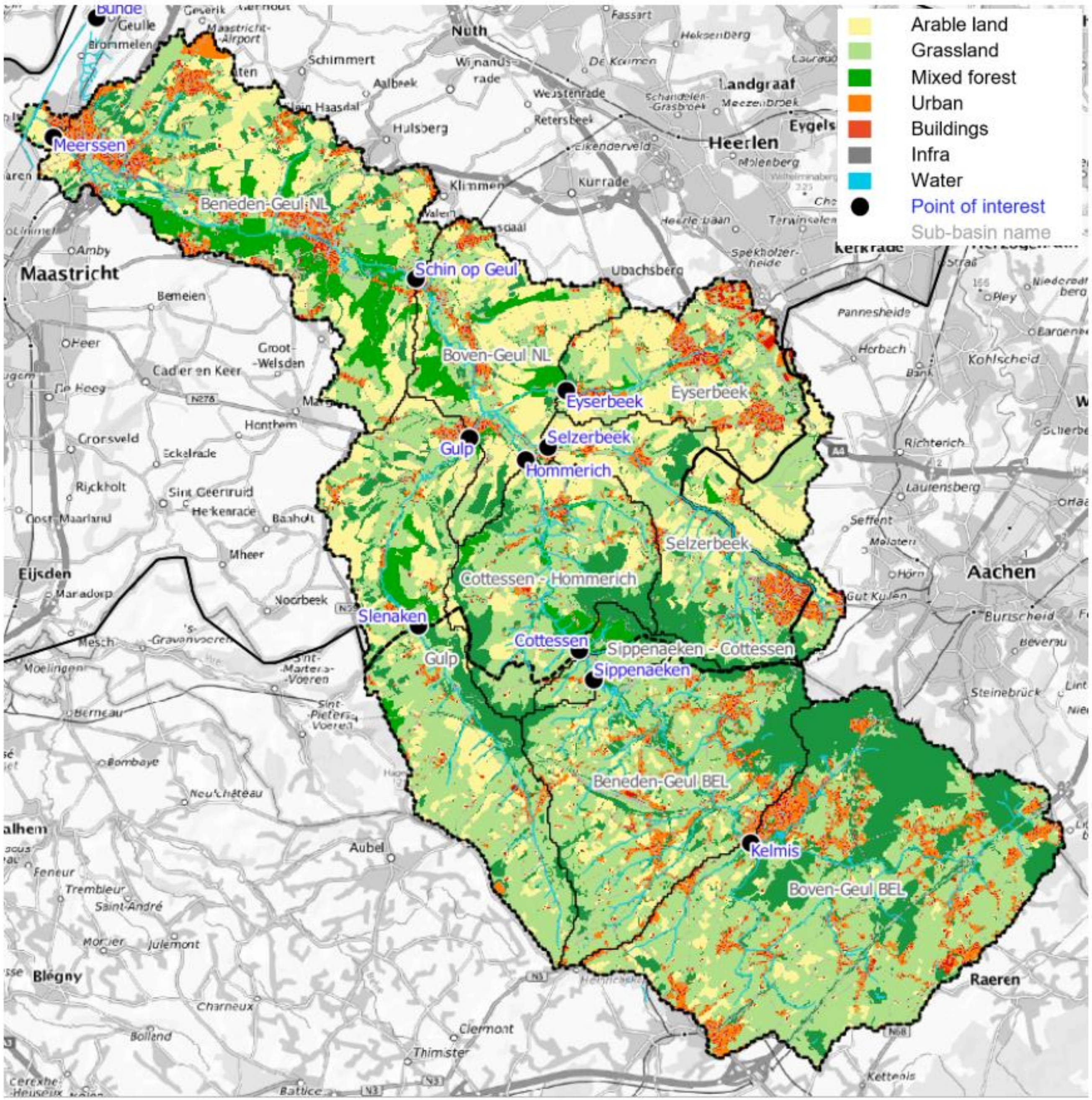
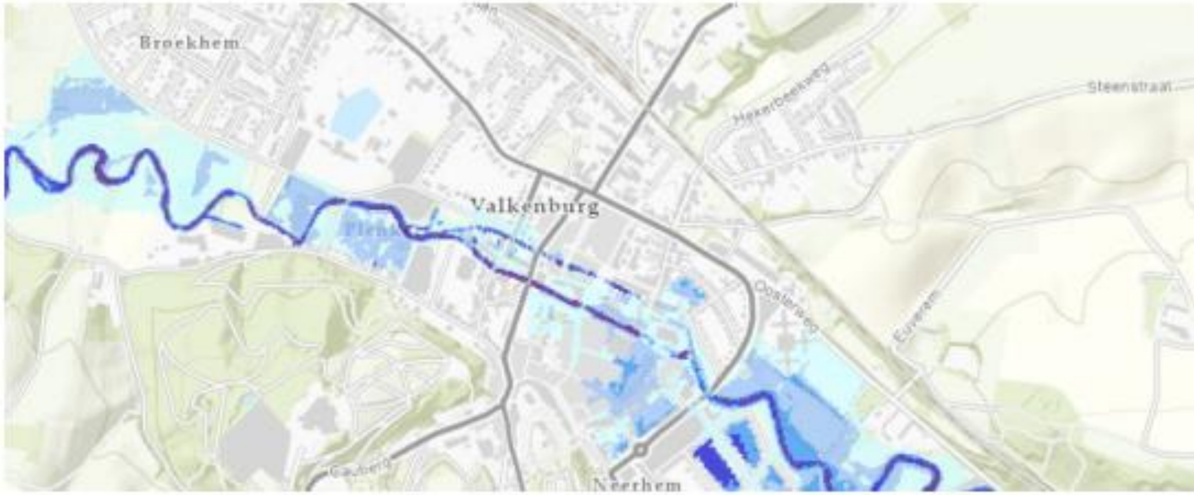
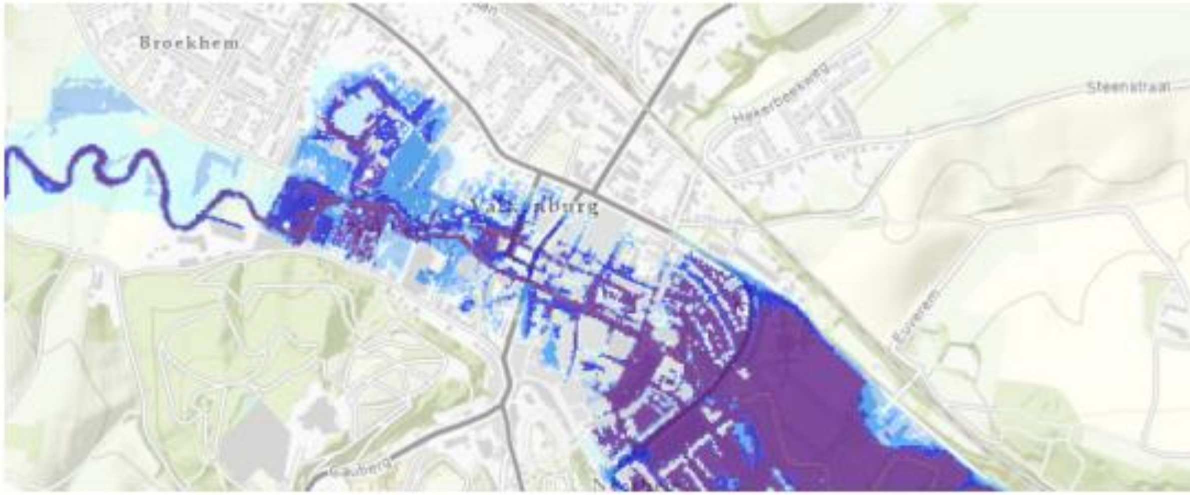


Figure 6: Detailed land use map of the Geul river basin

Figure 3.1: Flooded area in Valkenburg (Expertisenetwerk waterveiligheid (ENW), 2021)



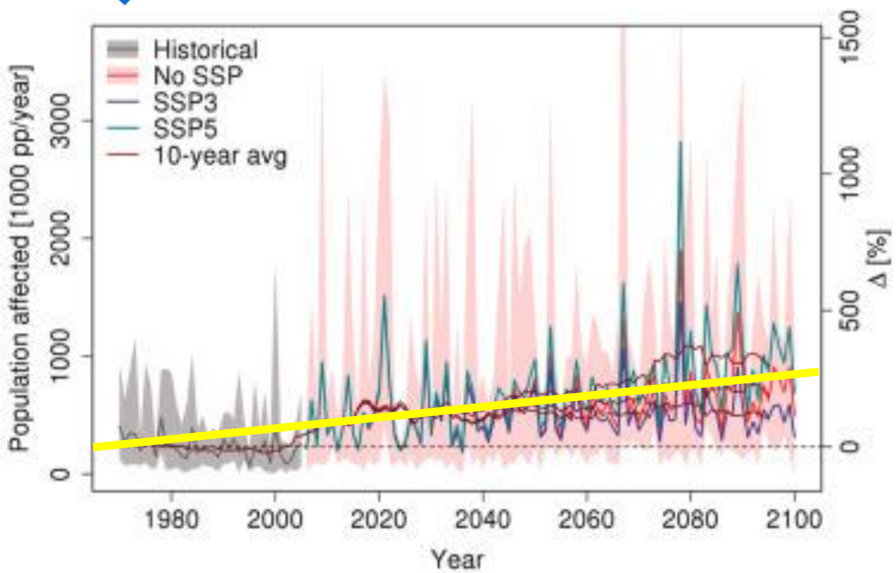
(a) Return period of 100 years

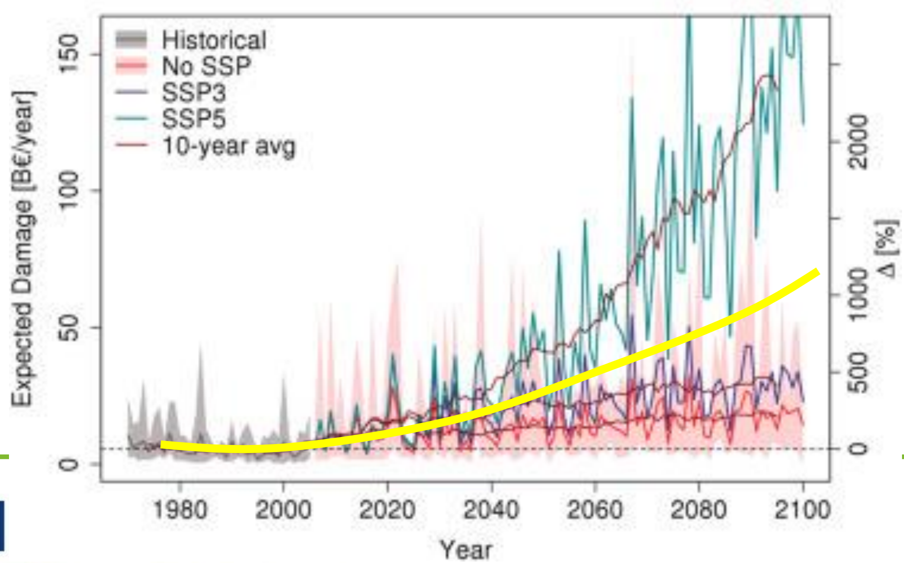


(b) Return period of 1000 years

Figure 3.2: Estimated flood area of Valkenburg for two events with a different return period (Risicokaart, 2019)

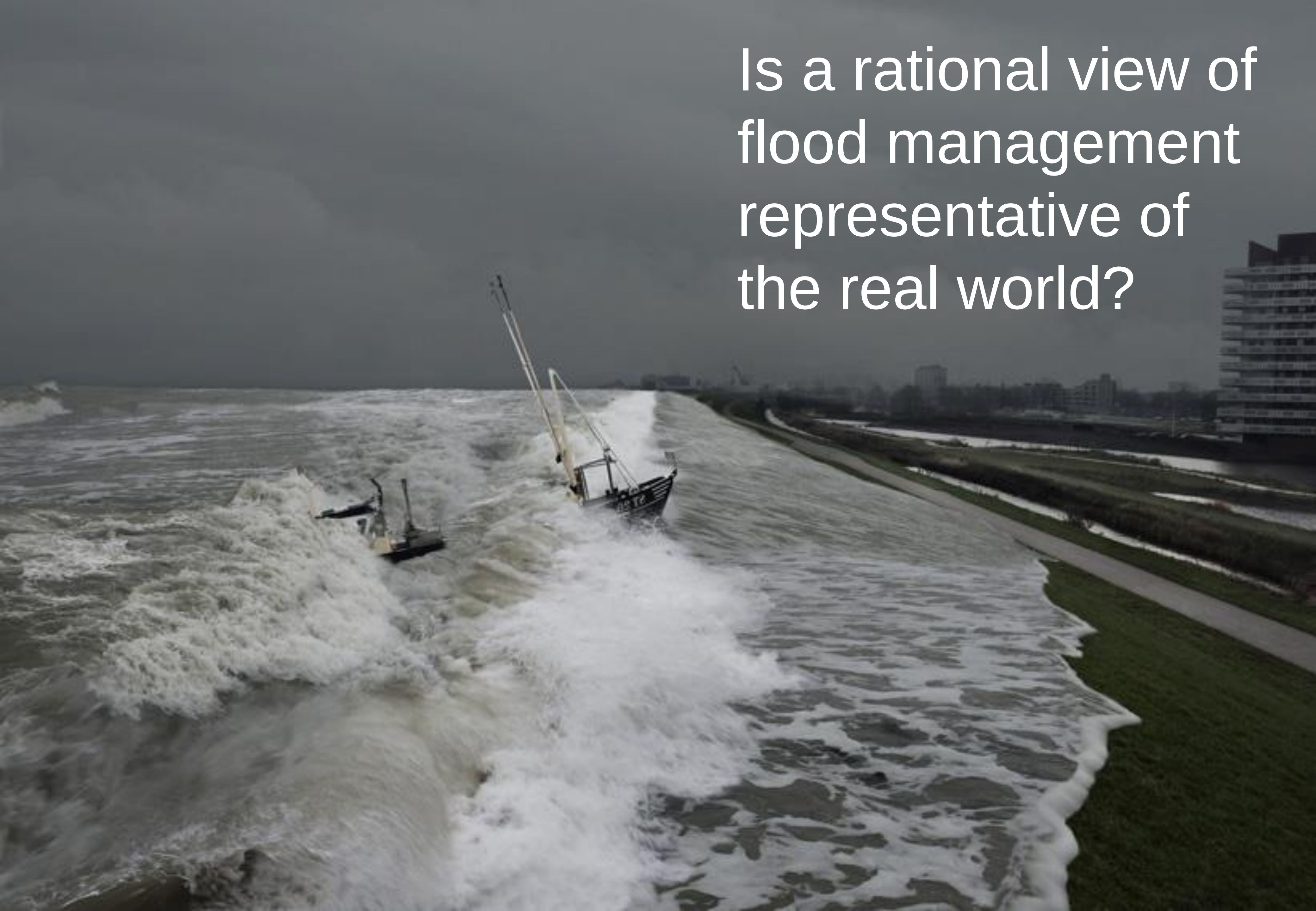
Flood risk assessment modelling





- Mostly upward trend in risk, damage, casualties
- Socio economic drivers have largest share in this trend
- Relative share of Climate change forcing will increase over the coming century


Is this enough?


Is a rational view of flood management representative of the real world?

Evacuation behavior

Being aware of an evacuation advice significantly drives evacuation decisions

	All		Geul		Meuse	
	Did not evacuate	Evacuated	Did not evacuate	Evacuated	Did not evacuate	Evacuated
Total	135 (44%)	173 (56%)	69 (47%)	78 (53%)	66 (41%)	95 (59%)
No advice to evacuate (according to respondent)	86 (81.1%)	20 (18.9%)	54 (81.8%)	12 (18.2%)	32 (80%)	8 (20%)
Received evacuation advice (according to respondent)	49 (24.3%)	153 (75.7%)	15 (18.2%)	66 (81.8%)	34 (28.1%)	87 (71.9%)

There is a group that is structurally unwilling to evacuate

	All		Geul		Meuse	
	Did not evacuate	Evacuated	Did not evacuate	Evacuated	Did not evacuate	Evacuated
Total	135 (44%)	173 (56%)	69 (47%)	78 (53%)	66 (41%)	95 (59%)
Certainly not evacuating	39 (28.9%)	0 (0%)	18 (26.1%)	0 (0%)	21 (31.8%)	0 (0%)
Probably not evacuating	74 (54.8%)	34 (19.7%)	42 (60.9%)	13 (16.7%)	32 (48.5%)	21 (22.1%)
Probably evacuating	18 (13.3%)	83 (48.0%)	6 (8.7%)	38 (48.7%)	12 (18.2%)	45 (47.4%)
Certainly evacuating	4 (3.0%)	56 (32.4%)	3 (4.4%)	27 (34.6%)	1 (1.5%)	29 (30.5%)

Conclusion and implications

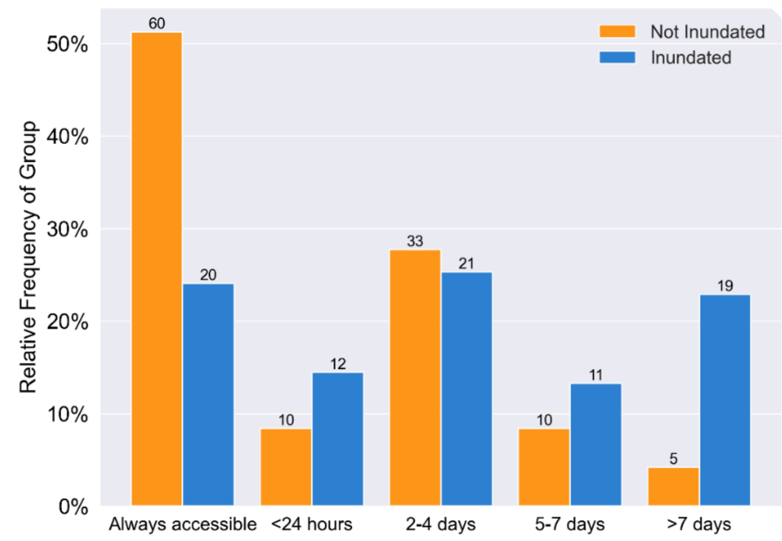
- Empirical estimates of business interruption duration and losses
- Stimulate firm insurance uptake and adaptation
- A strategy for firms to increase their resilience to disasters is by engagement with the local community
- Efficient and streamlined damage compensation reduces business interruption and thus, post-disaster losses

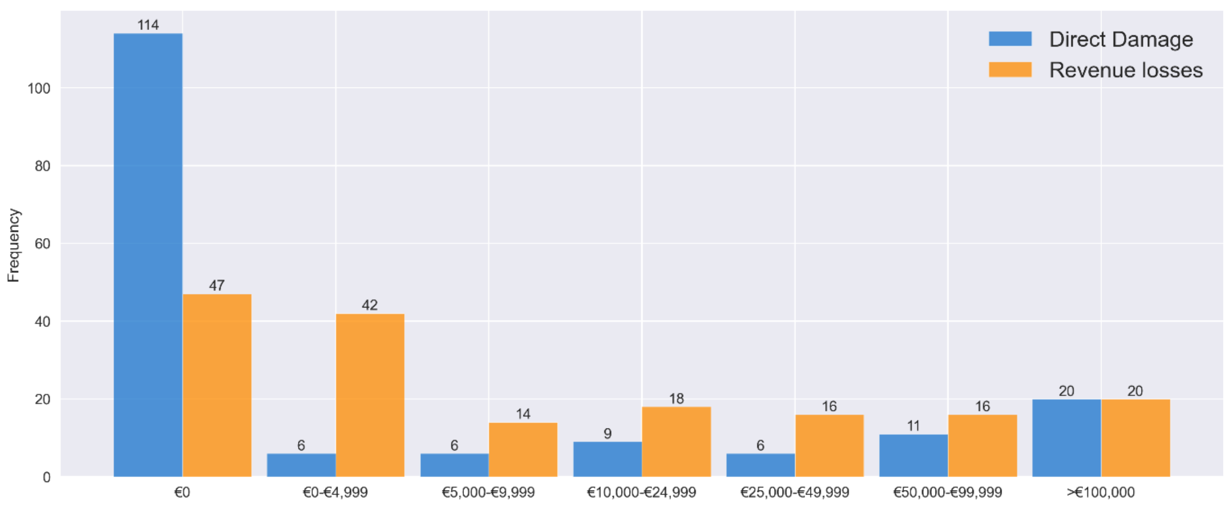
Firm impacts and resilience

Direct and indirect impacts to firms

39% flooded

56% of all firms faced business interruption





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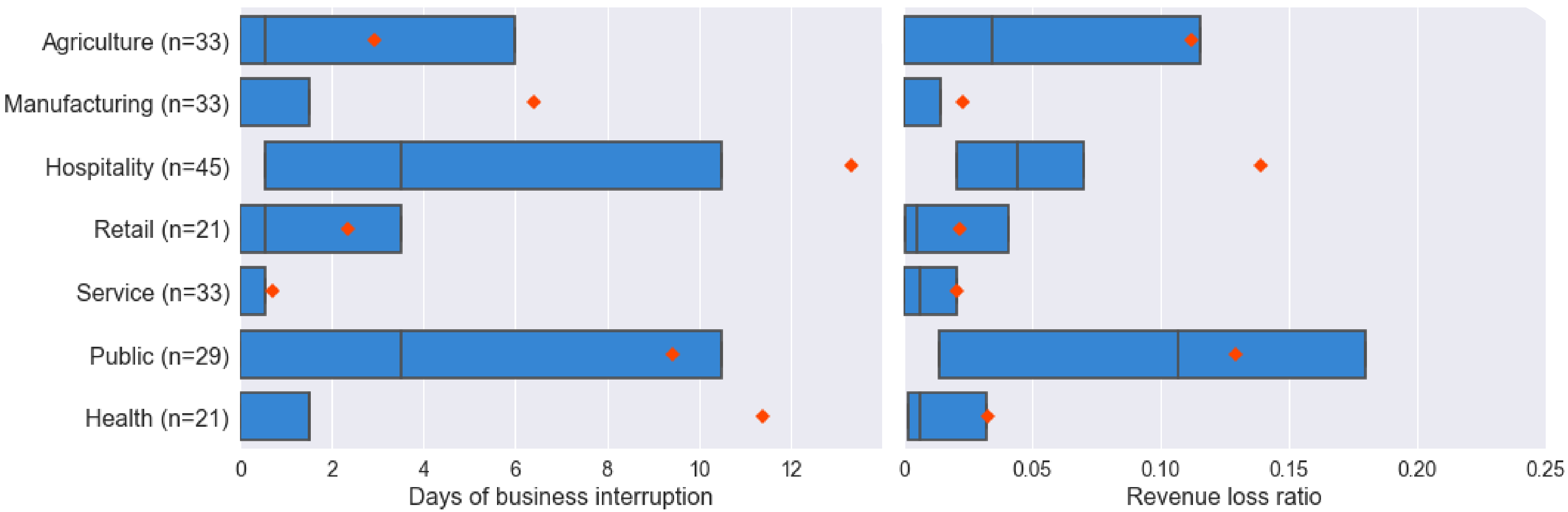
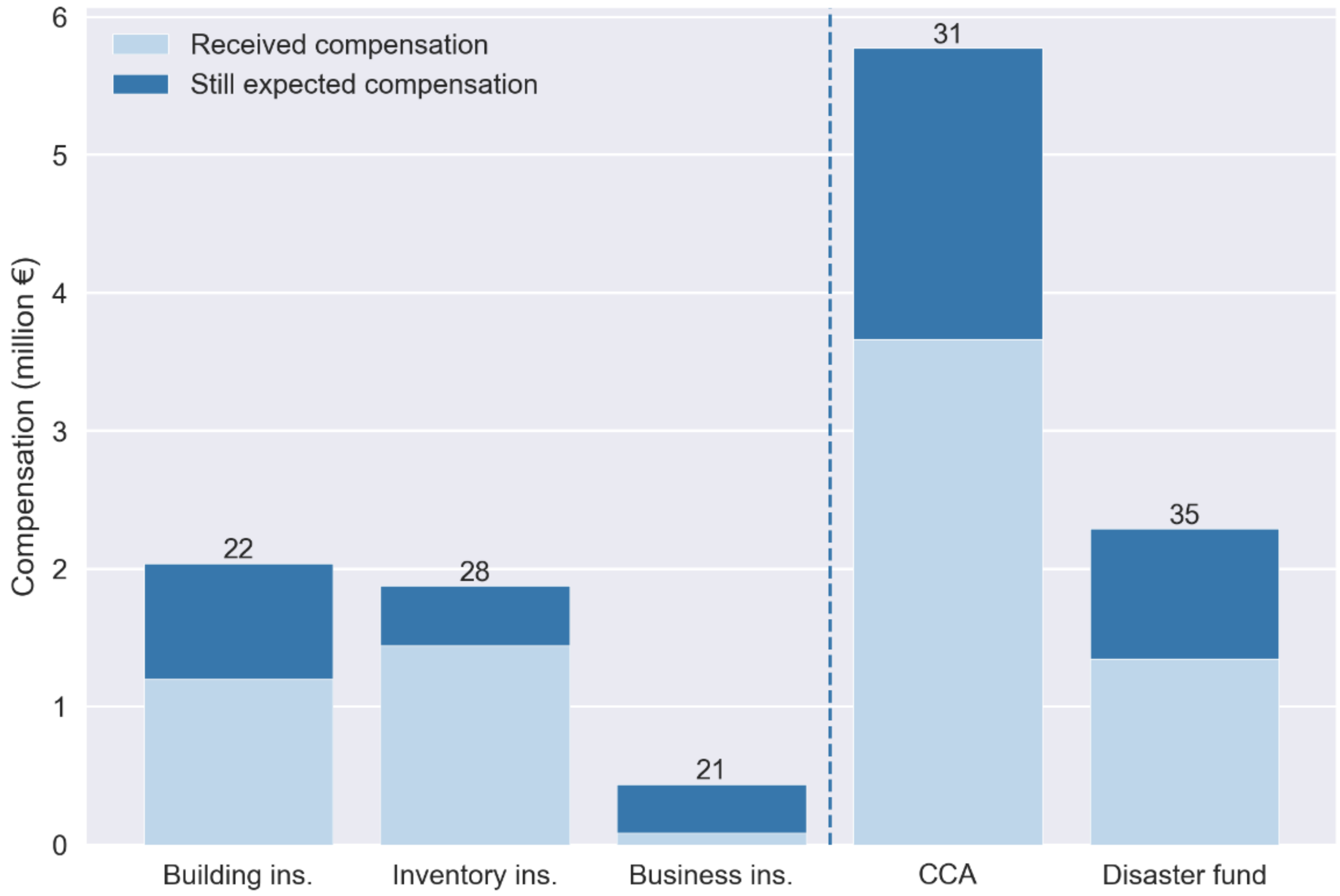
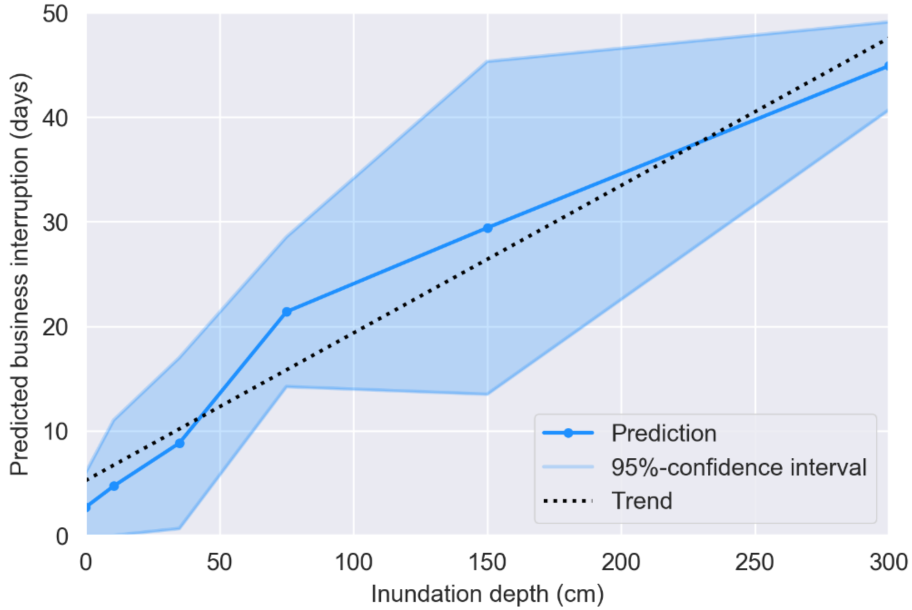
Business interruption and losses per sector

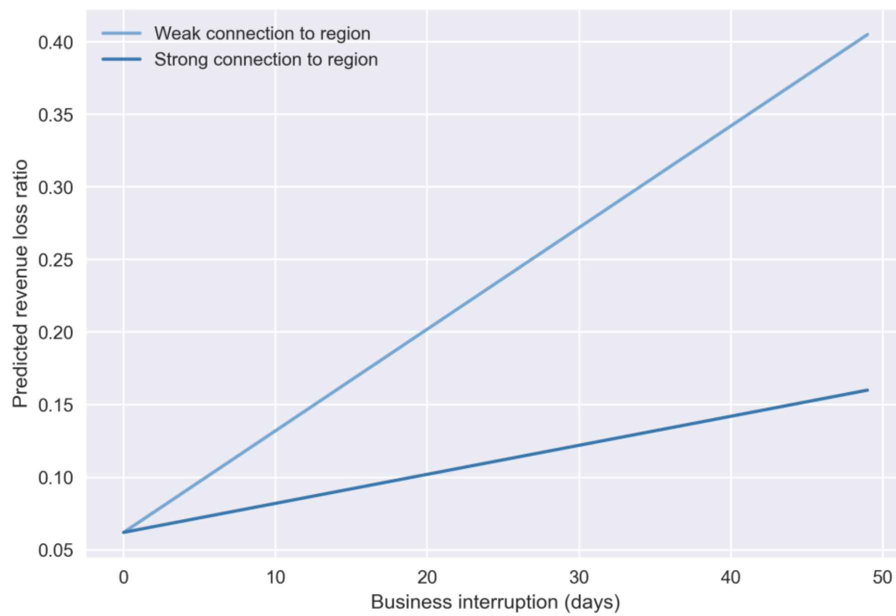


Insurance compensation



Business interruption duration and losses





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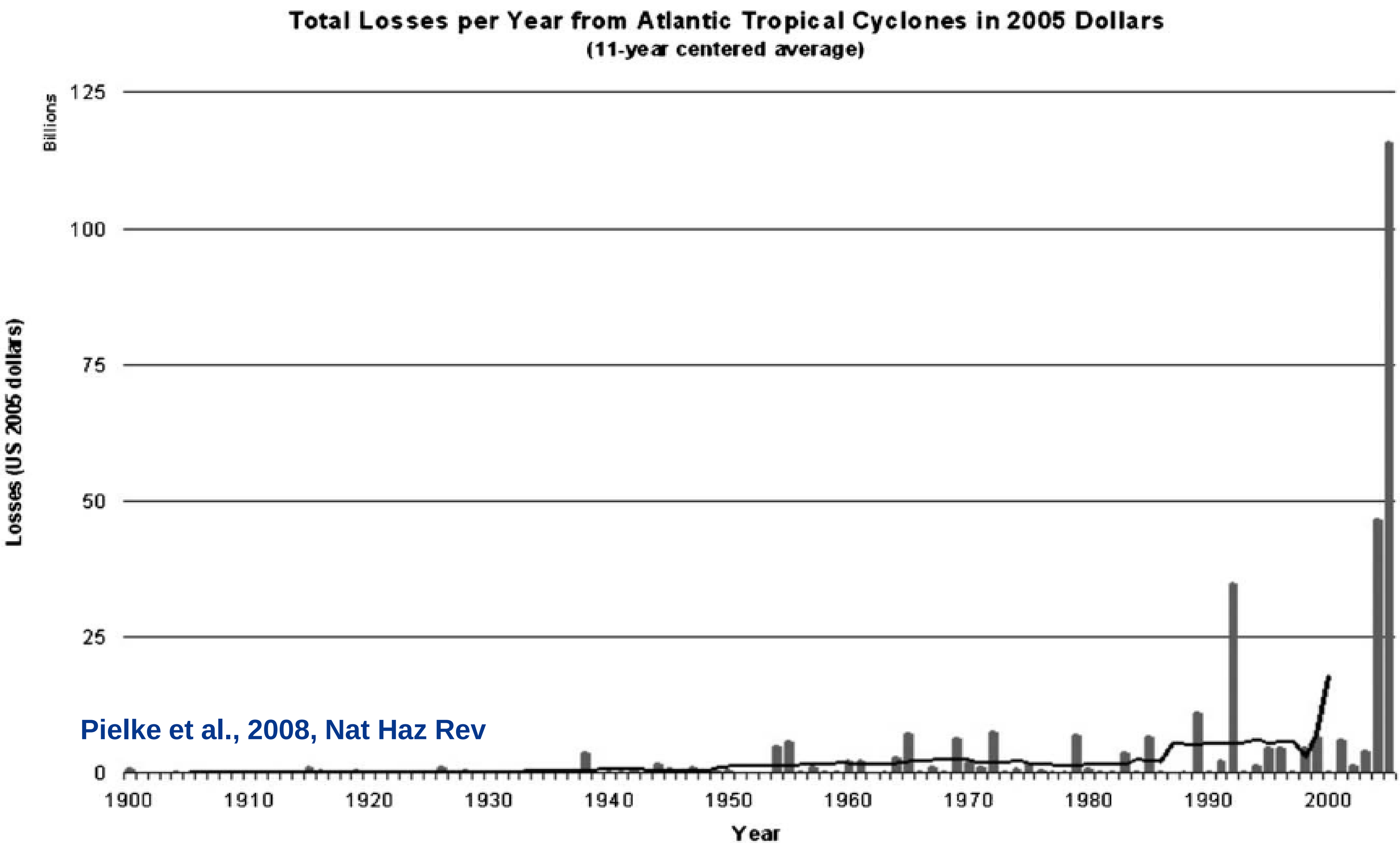
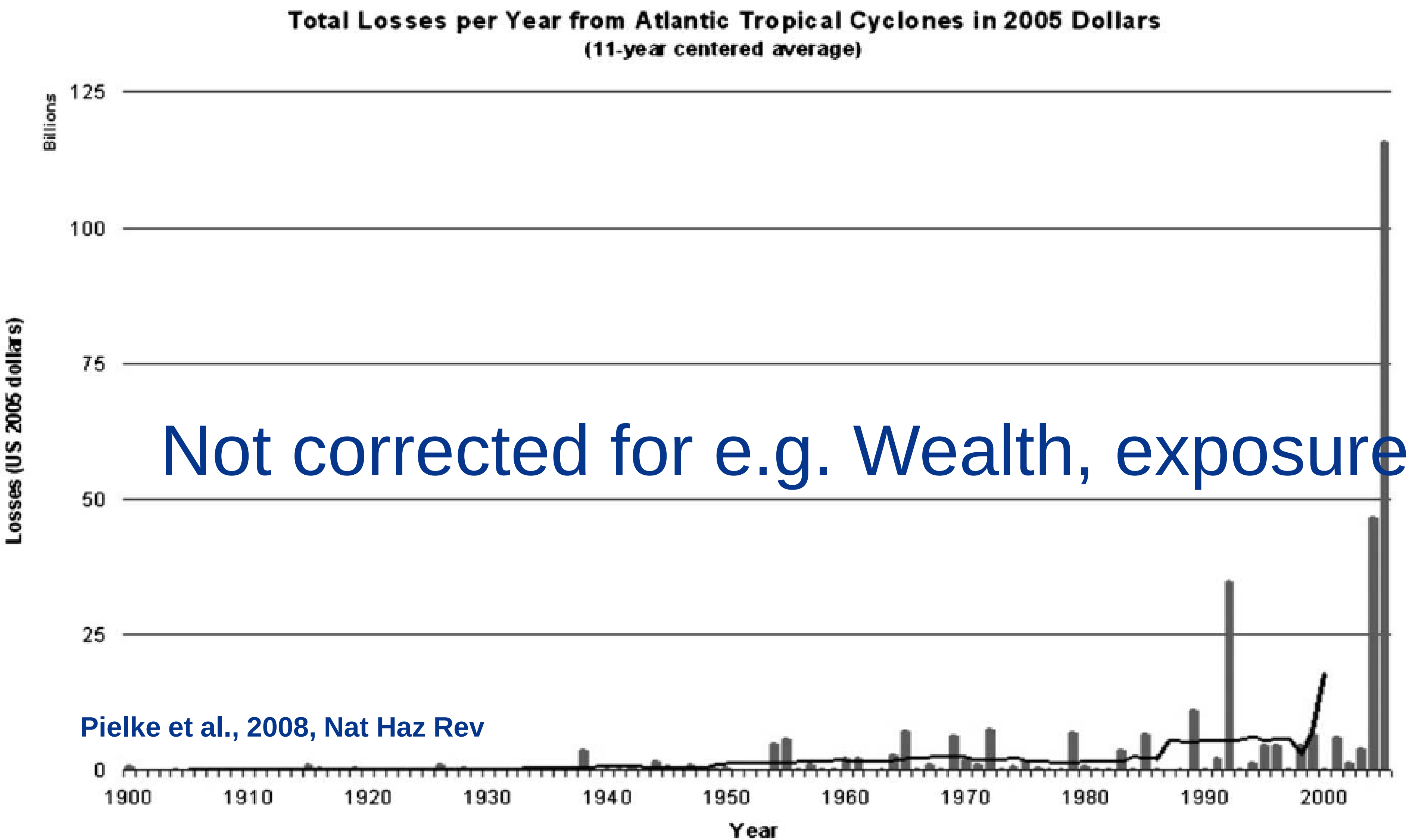
Trends in losses from hurricanes



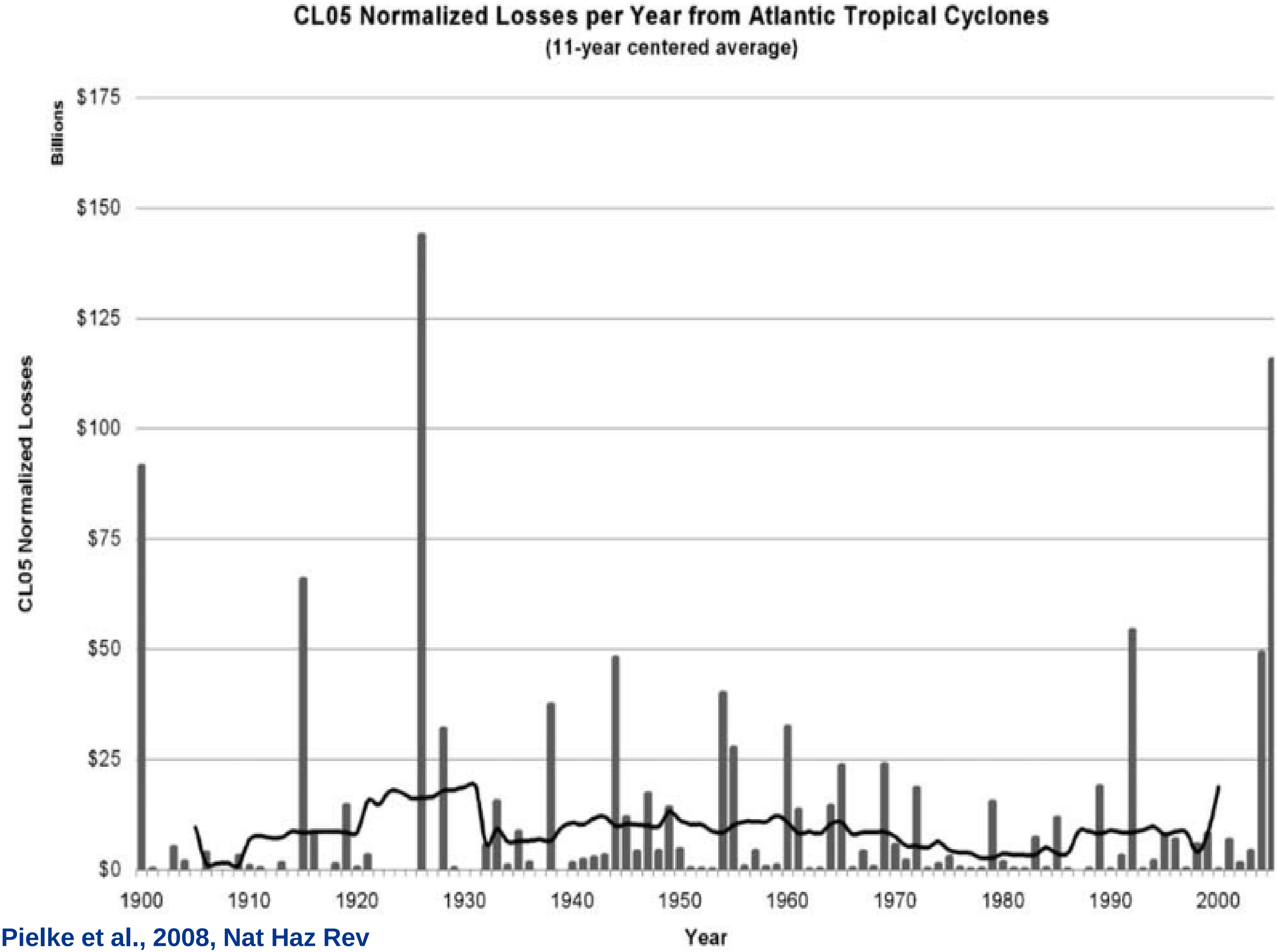
Pielke et al., 2008, Nat Haz Rev

Trends in Losses

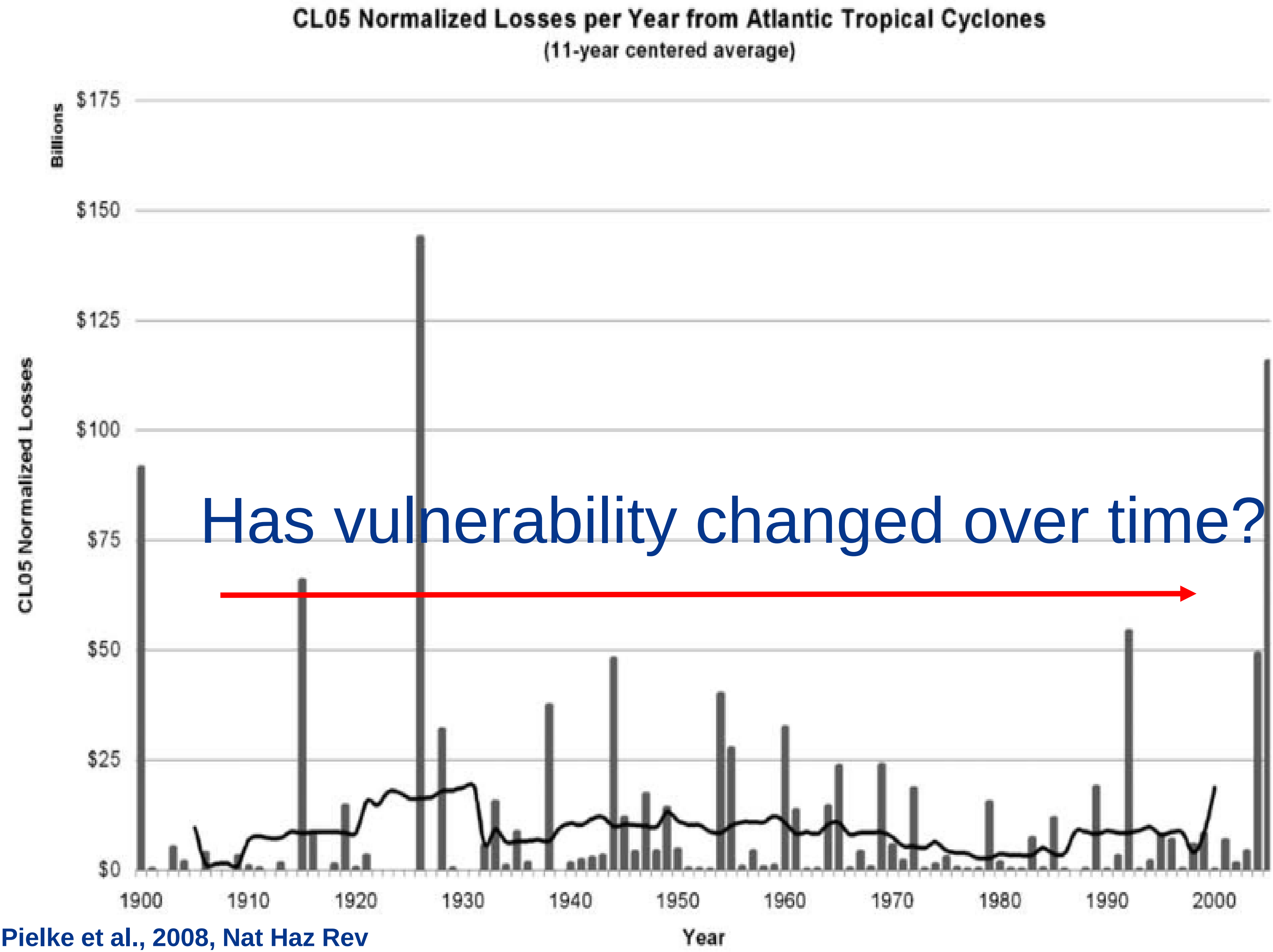


Not corrected for e.g. Wealth, exposure

Pielke et al., 2008, Nat Haz Rev



Pielke et al., 2008, Nat Haz Rev



Pielke et al., 2008, Nat Haz Rev