Public Adaptation Costs:
Investigating the National Adaptation

CAD-MUCI: Climate Change Effects – Adaptation and Municipal Cost Implication - Aktuelle Ergebnisse

Wolfgang Loibl,

Karoline Mitterer, Birgit Bednar-Friedl, Catrin Haider, Mario Köstl, Branislaw Iglar, Gerhard Heiss, Anita Haindl, Nikola Hochholdinger,Gabriel Bachner

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Project Background and Objectives

Extreme Events‘ magnitude and frequency will grow in future climate

Climate Adaptation

- shall lead to a reduction of damage of future climate conditions and events.
- Not only local adaptation measures may have an impact,
- spillover effects of measures from neighbouring municipalities either in close or greater distance may have an impact too.

The general objectives of this project are

- to explore municipalities’ budgetary effects of adaptation measures against flood risk by analysing costs of damage repair before and after measure implementation
- to analyse the presence of spillover effects from distant adaptation measures
- to examine adaptation or maladaptation impact of current and potential future events of similar scope for municipalities

Tasks carried out

- Extreme events exploration:
  - heavy precipitation events, floods 2002 – 2013
- Delineation of study area: rivers, catchments, municipalities

- Budget analysis 2002-2014 of all (153) municipalities in the study catchments

- Geospatial data acqusition, compilation, analysis of risk exposure

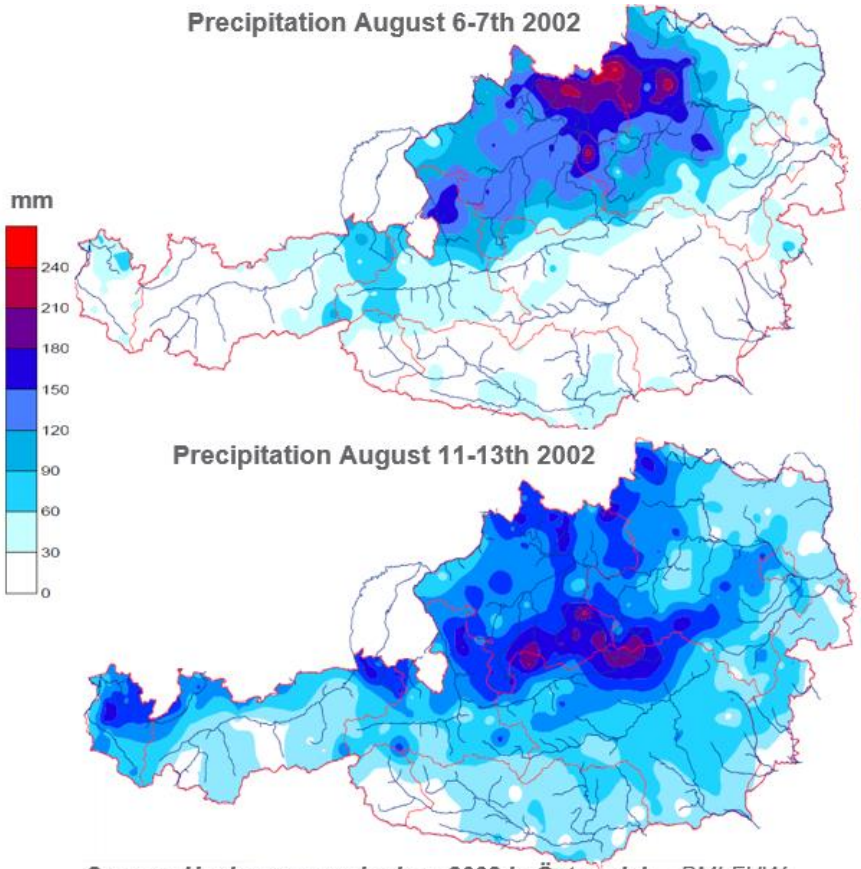
- Statistical analysis of damage repair costs and change of costs

  versus
  - spatial characteristics and
  - adaptation costs during the years between heavy extreme events

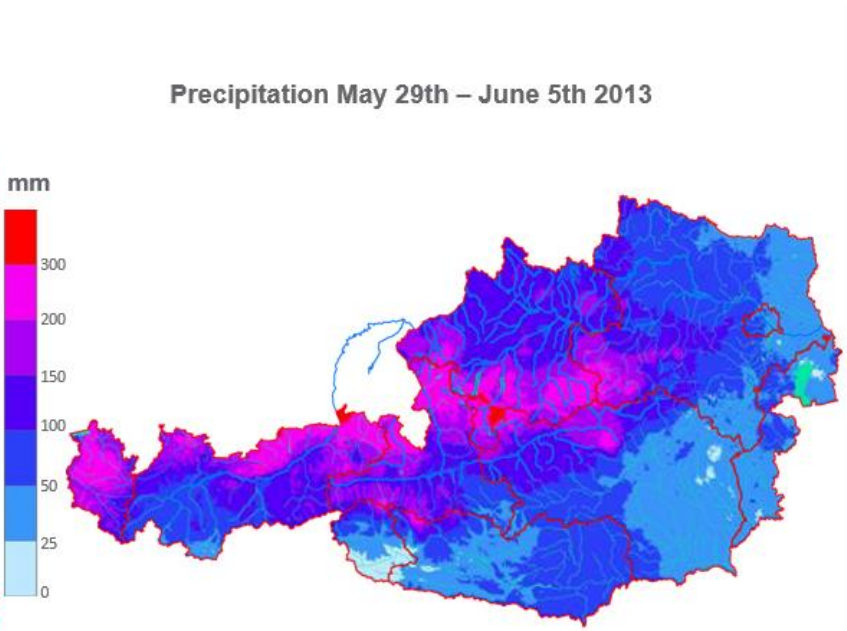
- Case studies: interviews in selected municipalities to gain deeper insights
  - on damage, adaptation and costs of local, upstream and downstream measures,
  - on institutional instruments to share risk and costs

- Examine adaptation /maladaptation impact of extreme events during future climate

Observed extreme event periods to explore damage & adaptation costs and interrelations: 2002 - 2013



Source: ***Hochwasserereignisse 2002 in Österreich*** – *BMLFUW, Abteilung VII/3 Wasserhaushalt*



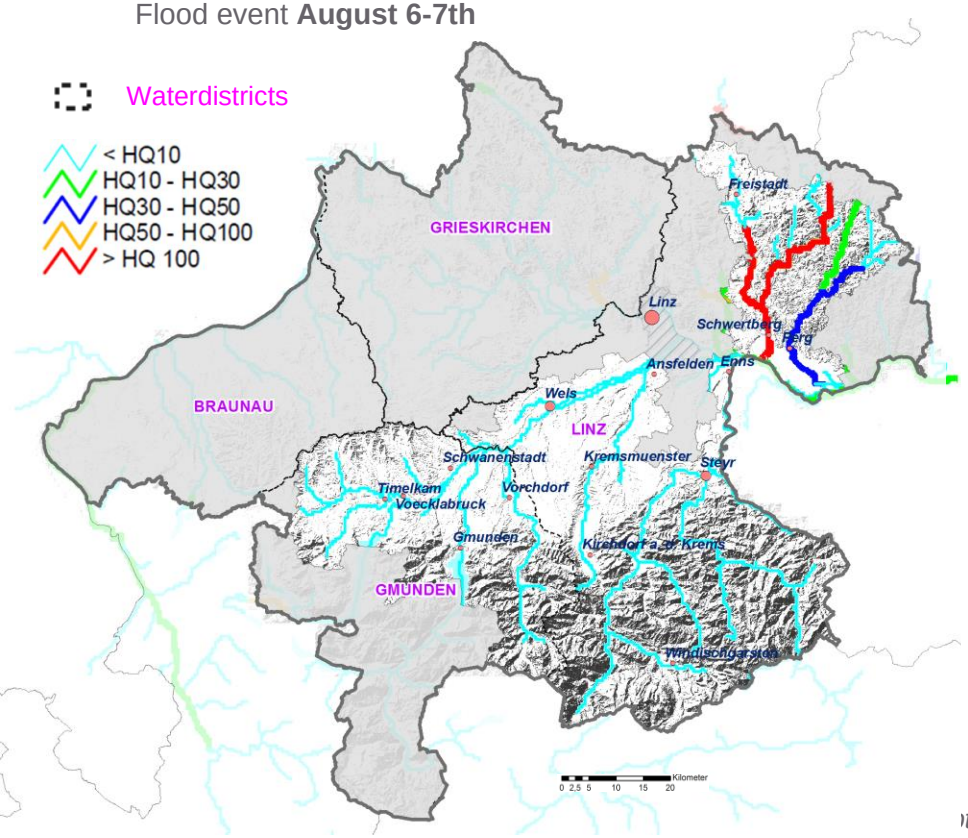
Source: ***Die hydrographische Analyse des Hochwassers im Juni 2013*** - *Abteilung IV/4 Wasserhaushalt*

Case study catchments

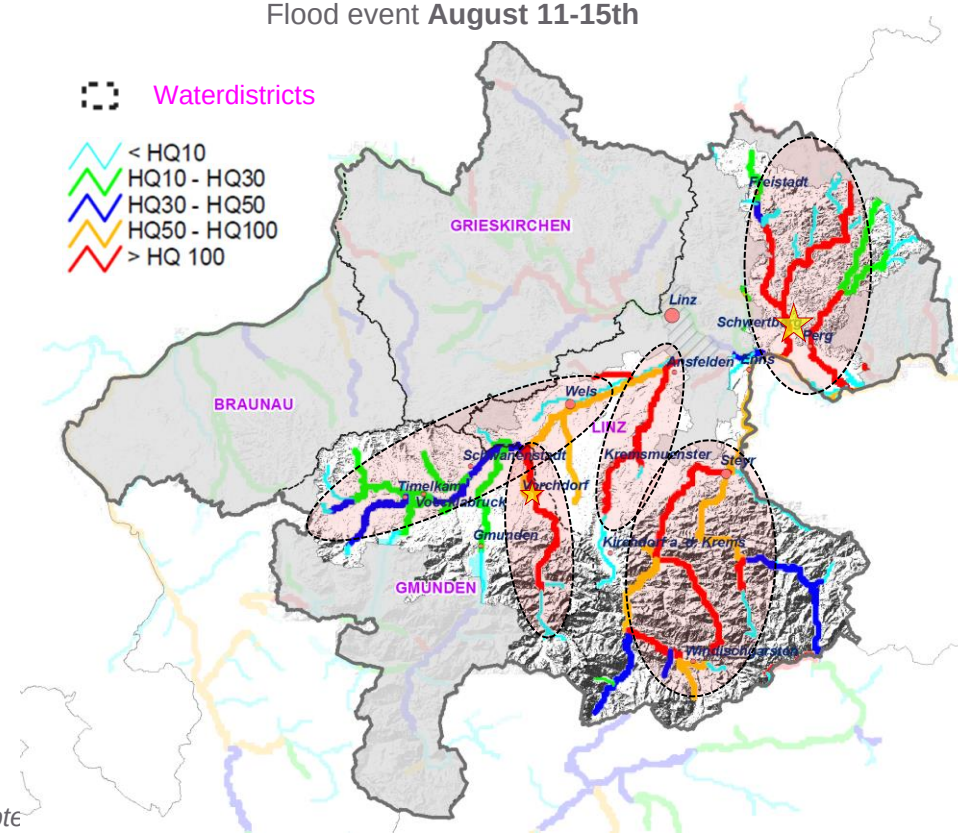
Start year 2002 – dramatic floods in Upper Austria

Case study catchments Vöckla-Ager-Alm-Traun / Steyr-Enns / Krems / Aist-Naarn

Flood event **August 6-7th**



Flood event **August 11-15th**



https://www.bmlfuw.gv.at/wasser/wasser-oesterreich/wasserkreislauf/hydrograph_charakt_extrema/Hochwasser2002.html

Case study catchments

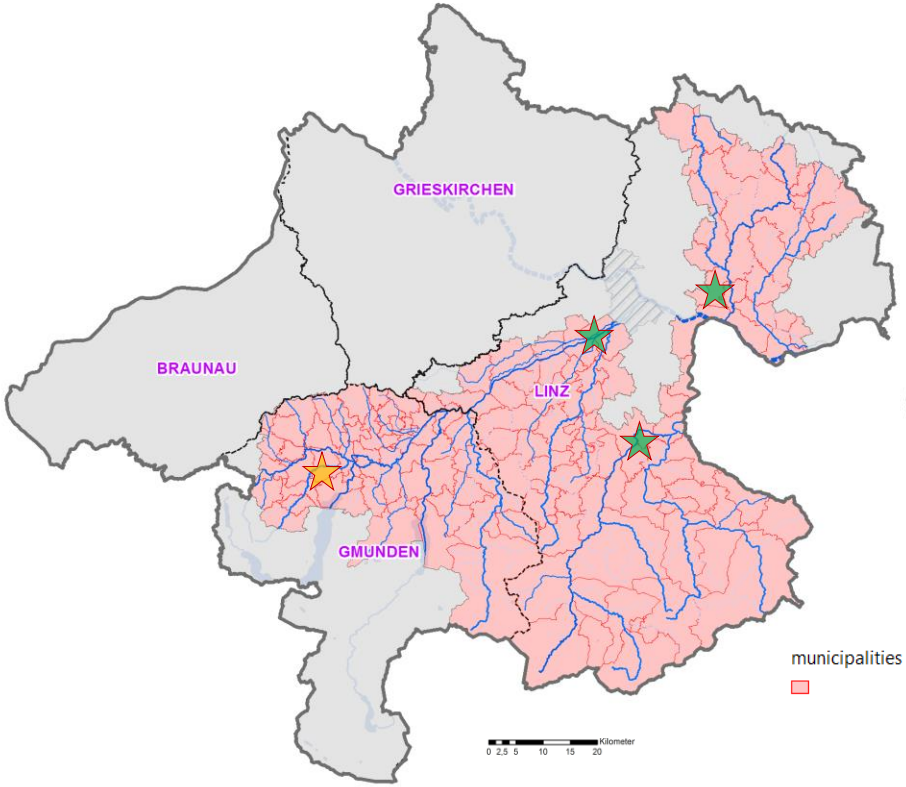
The study area

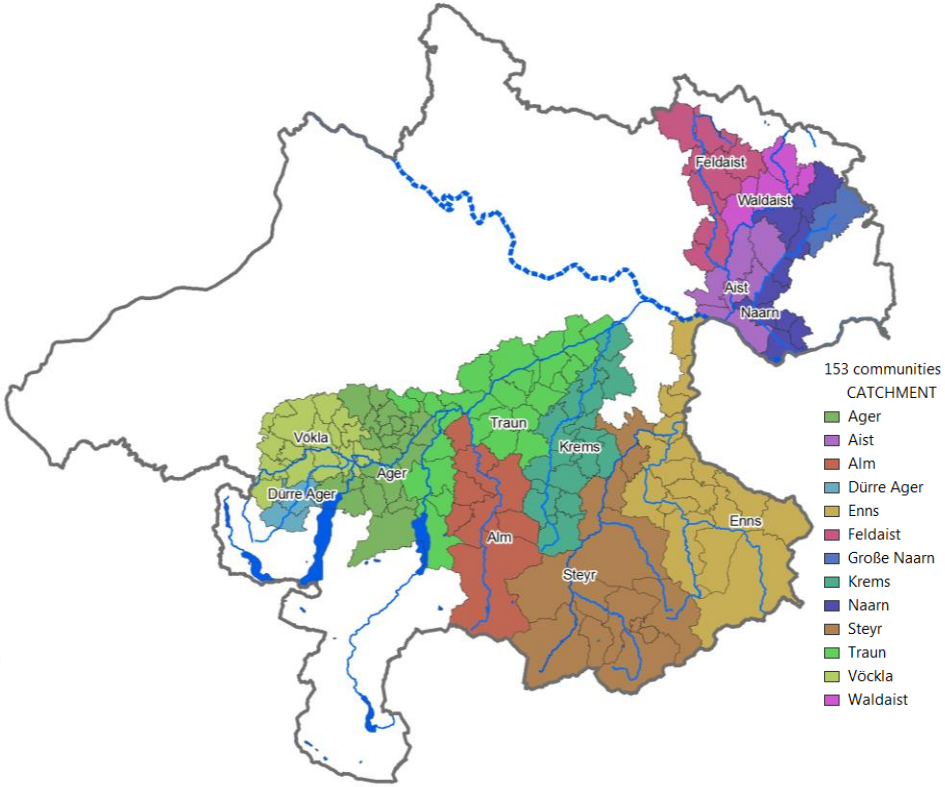
Workbase is municipality level

main catchments associated to municipalities

Case study municipalities: Vöcklabruck-Timelkam / Steyr / Ansfelden / Schwertberg

Cases visited (★) and planned visits (☆)



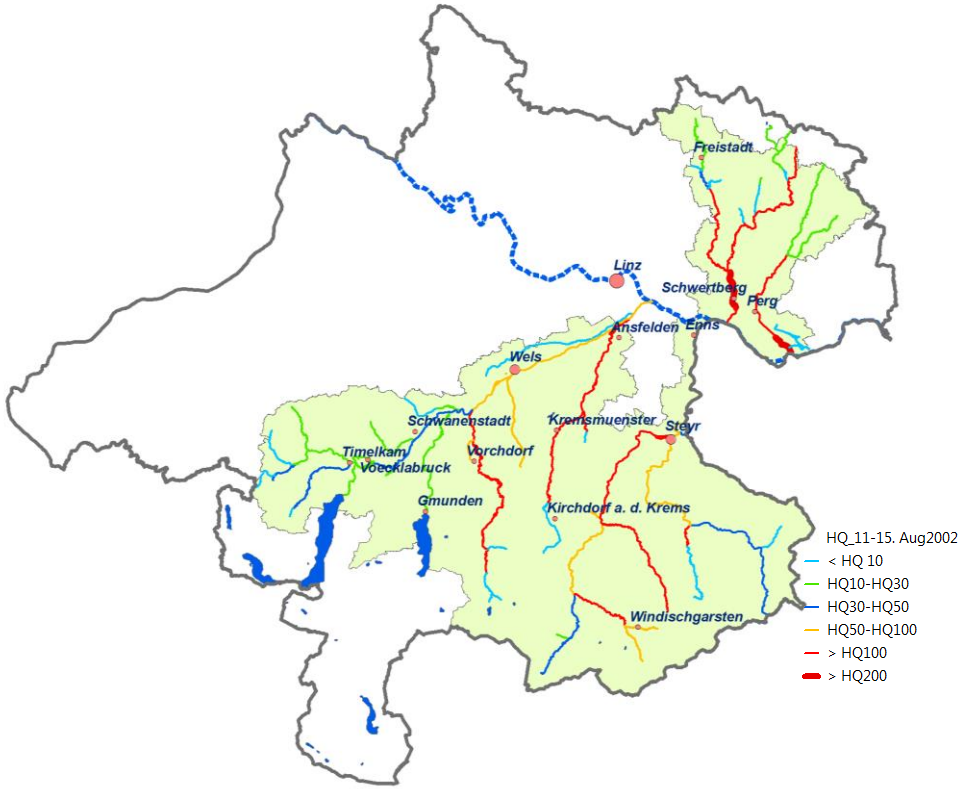


Case study catchments:

Identifying affected municipalities / settlements 2002, risk 2013

Reported flooded areas 2002
but apparently not complete (e.g. Steyr, Schwertberg,…)

N**o flooding polygons for 2013!**
Therefore **estimation of risk potential by HQ-polygons** (OGD Upper Austria)…

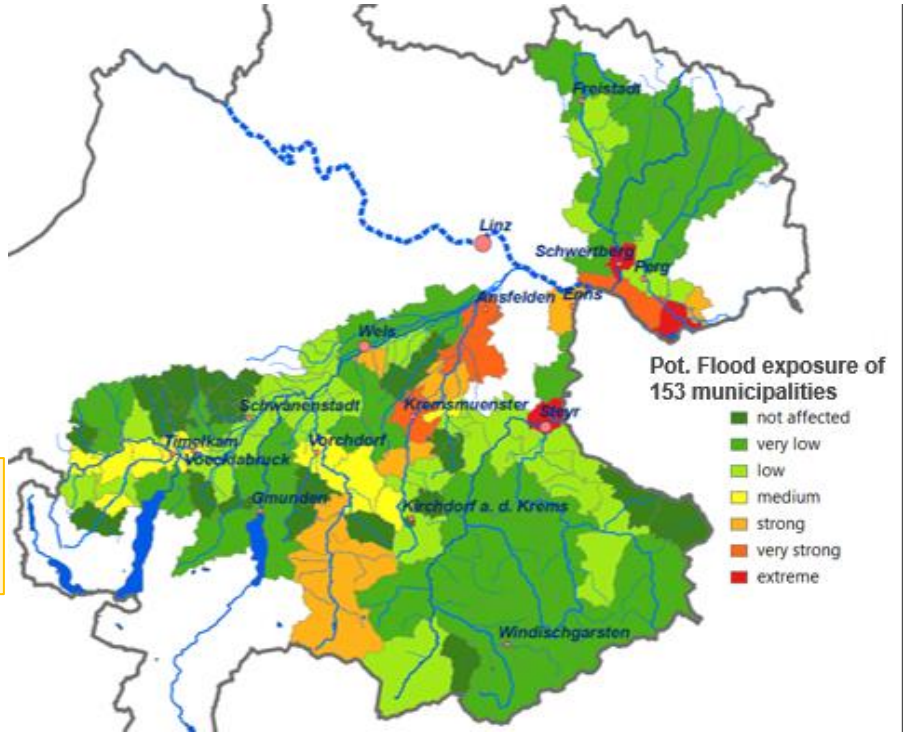


Flood risk exposure assessment of municipalities in case study catchments

Data for (qualitative) risk assessment:

- Reported flooded areas 2002
- HQ10, HQ30, HQ100 flood risk polygons
- Elevation distance :
  valley floor to potentially exposed settlement area
- Distance :
  valley floor to potentially exposed settlement area

affection 2002	cnt. Munici-palities	Aist	Feldaist	Waldaist	Naarn	Vöckla	Dürre Ager	Ager	Traun	Alm	Krems	Enns	Steyr
extreme	3	1			1							1	
very strong	6	2									4		
strong	8				1				1	2	3	1	
medium	12					5	1	2		2	2		
low	35		3		3	2	1	5	9	1	5	4	3
very low	60	4	6	4	5	3		7	14			6	10
not affected	29					5	1	8	5	3	4	2	1
total	**153**	**7**	**9**	**4**	**10**	**15**	**3**	**22**	**29**	**8**	**18**	**14**	**14**



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- Delineation of study area: rivers, catchments, municipalities
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  - spatial characteristics and
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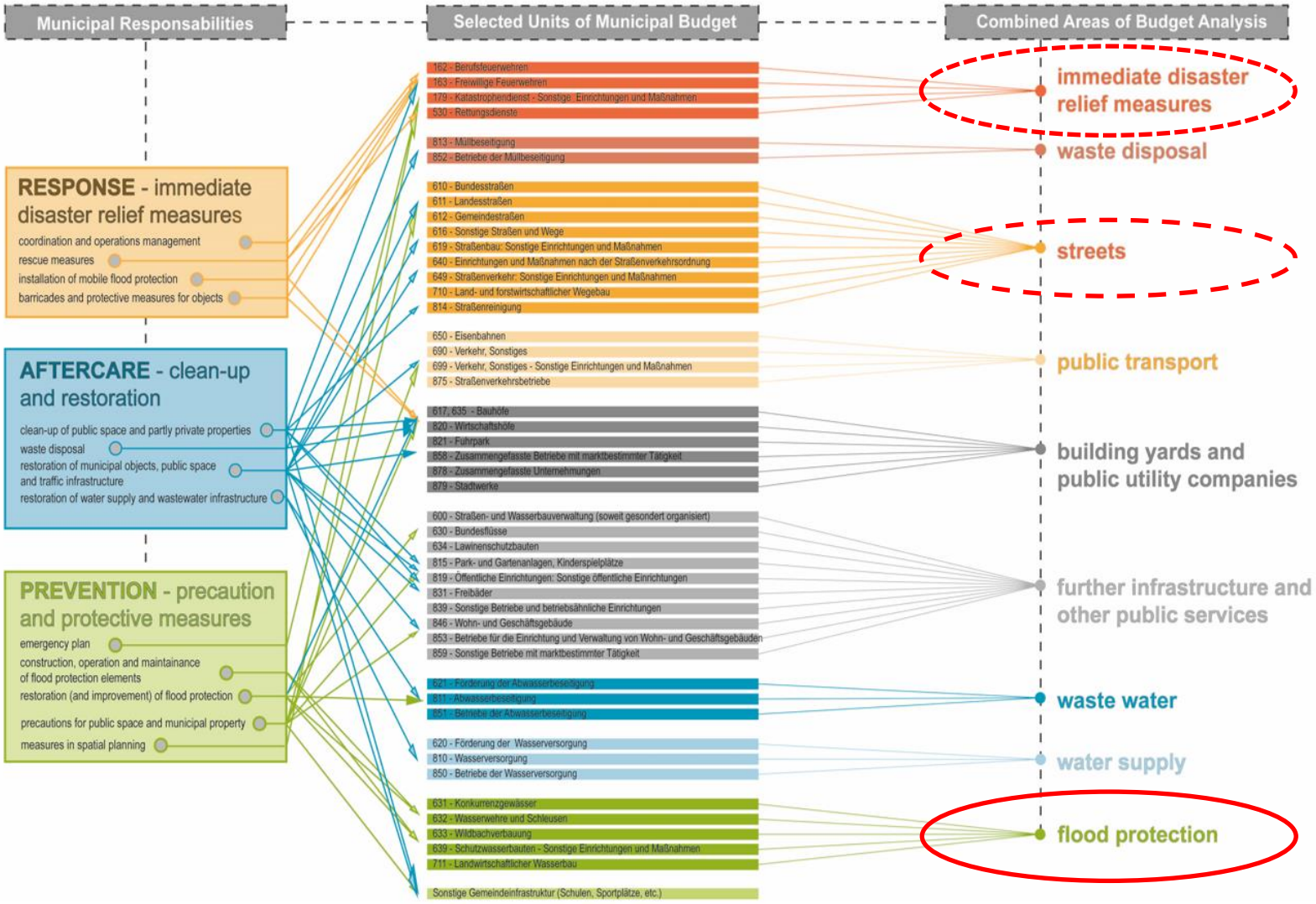
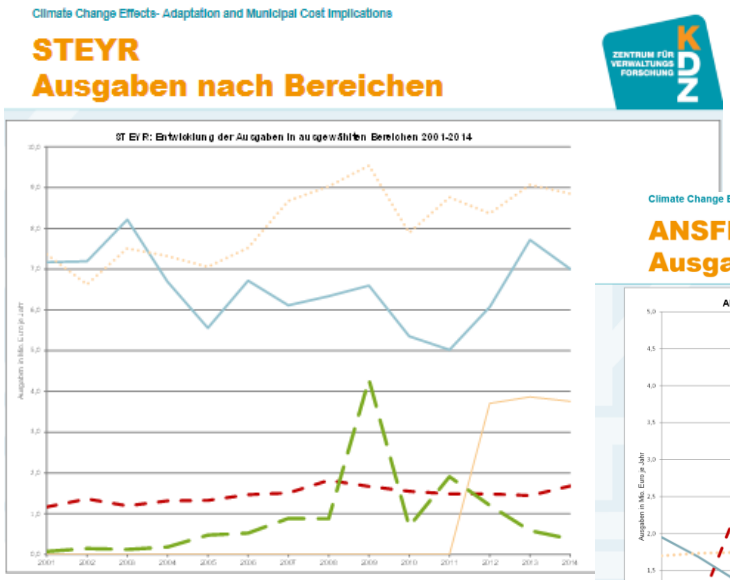
Budget-Analysis:

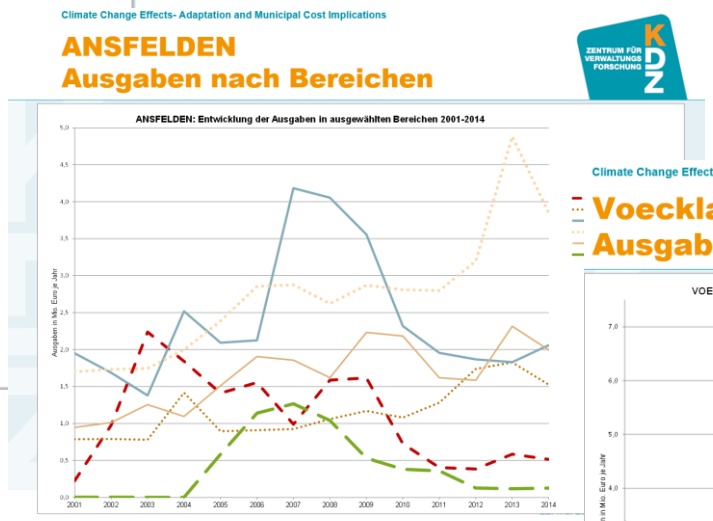
Responsibilities related to budget units and to budget „areas“ addressing repair and climate adaptation on extrem events municipalities)

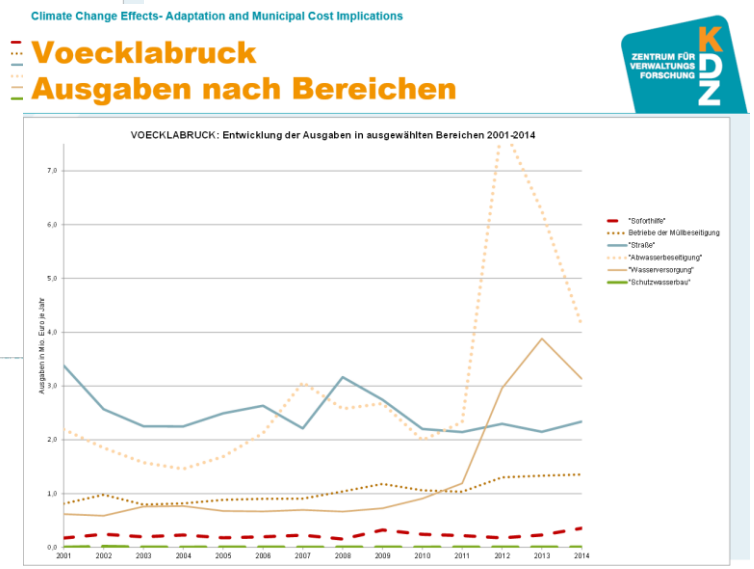


Graphical Analysis for selected case study budgets:

Timeline of municipal expenditures 2001 - 2014



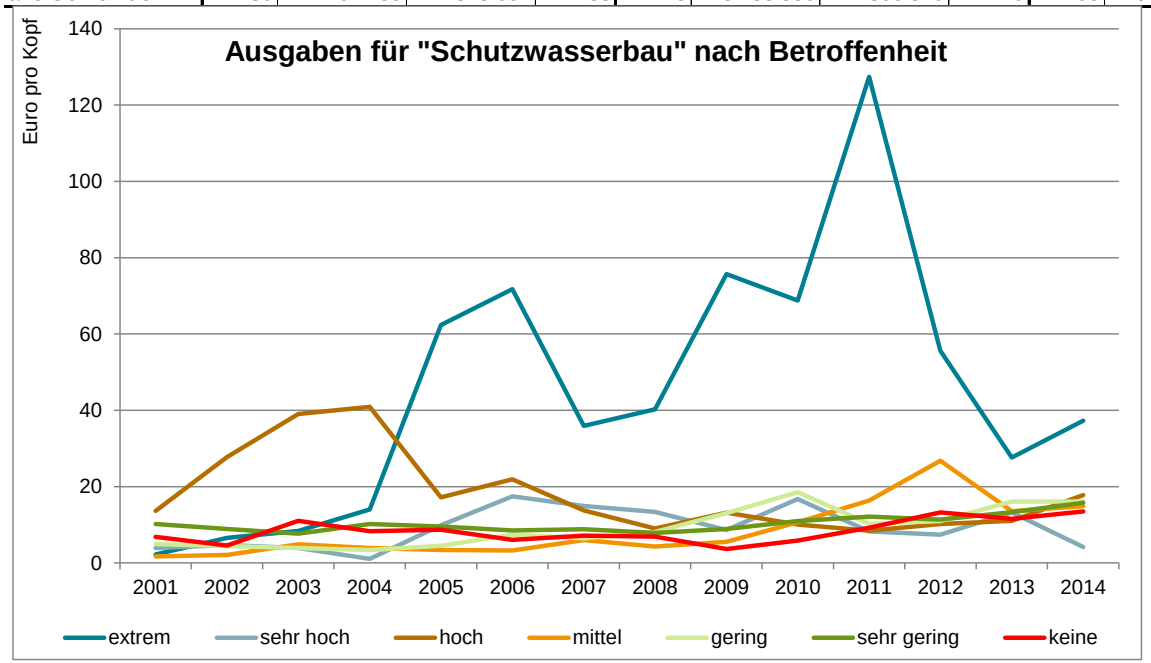


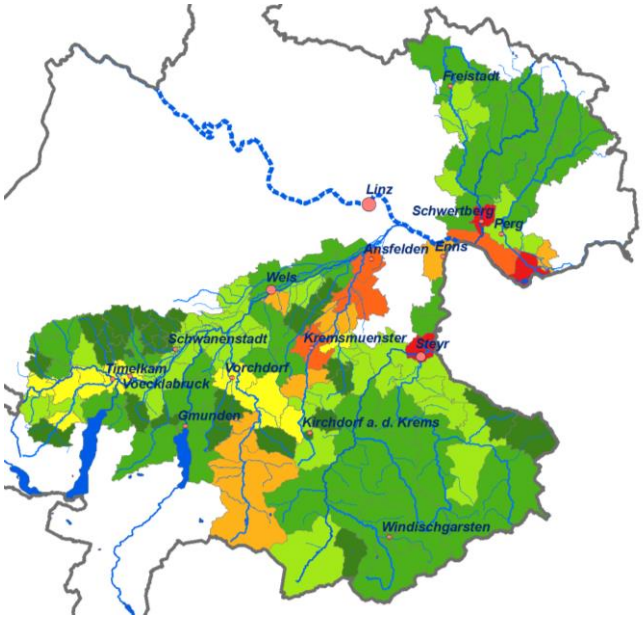


- "Soforthilfe"
- Betriebe der Müllbeseitigung
- "Straße"
- "Abwasserbeseitigung"
- "Wasserversorgung"
- "Schutzwasserbau"

Budget Analysis: water protection expenditures by catchment and potential flood risk exposure groups

	Aist-Naarn				Steyr-Enns				Traun				alle Catchments			
Ausgaben für Schutzwasserbau	Anzahl Gemeinden	Summe Ausgaben 01-14	Ø Ausgaben pro Jahr	Ausgaben pro Kopf	Anzahl Gemeinden	Summe Ausgaben 01-14	Ø Ausgaben pro Jahr	Ausgaben pro Kopf	Anzahl Gemeinden	Summe Ausgaben 01-14	Ø Ausgaben pro Jahr	Ausgaben pro Kopf	Anzahl Gemeinden	Summe Ausgaben 01-14	Ø Ausgaben pro Jahr	Ausgaben pro Kopf
extrem	2	7.413.452	529.532	1.078	1	12.342.671	881.619	324			0	0	3	19.756.123	1.411.152	439
sehr hoch	2	744.183	53.156	87			0	0	4	6.617.899	472.707	203	6	7.362.083	525.863	179
hoch	1	185.522	13.252	111	1	2.027.503	144.822	176	6	5.013.589	358.114	255	8	7.226.614	516.187	220
mittel			0	0			0	0	12	4.820.846	344.346	85	12	4.820.846	344.346	85
gering	5	1.526.683	109.049	83	7	3.485.419	248.958	135	23	5.329.192	380.657	78	35	10.341.294	738.664	92
sehr gering	20	1.591.314	113.665	31	16	6.724.059	480.290	188	24	19.720.772	1.408.627	110	60	28.036.145	2.002.582	106
keine			0	0	3	708.685	50.620	166	26	3.845.130	274.652	92	29	4.553.815	325.272	99
alle Gemeinden	**30**	**11.461.155**	**818.654**	**133**	**28**	**25.288.336**	**1.806.310**	**219**	**95**	**45.347.429**	**3.239.102**	**114**	**153**	**82.096.920**	**5.864.066**	**137**





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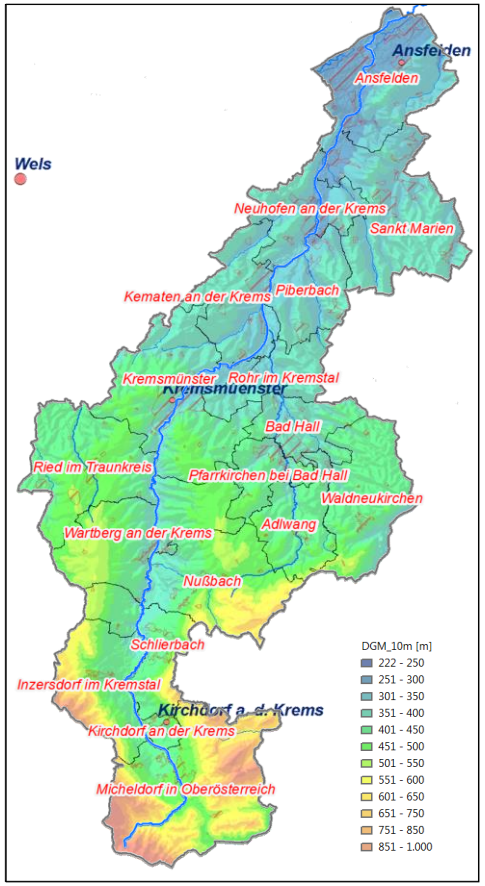
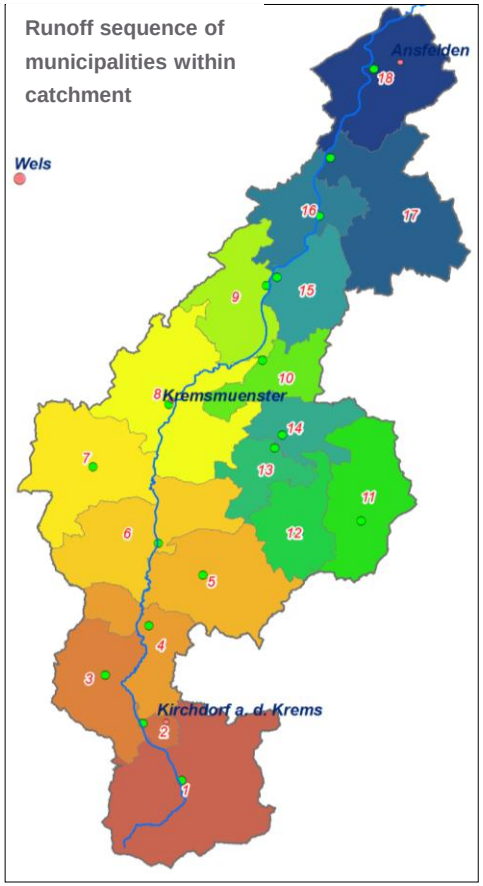
Geospatial data acquisition – selected data for statistical analysis explaining spatial impact on damage costs

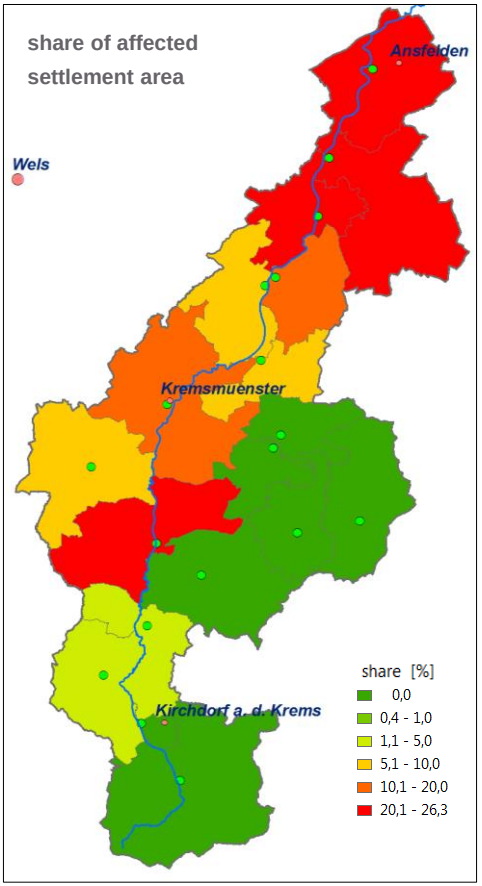
→ Example: Kremstal catchment,
Terrain and runoff sequence of municipalities for upstream costs aggregation

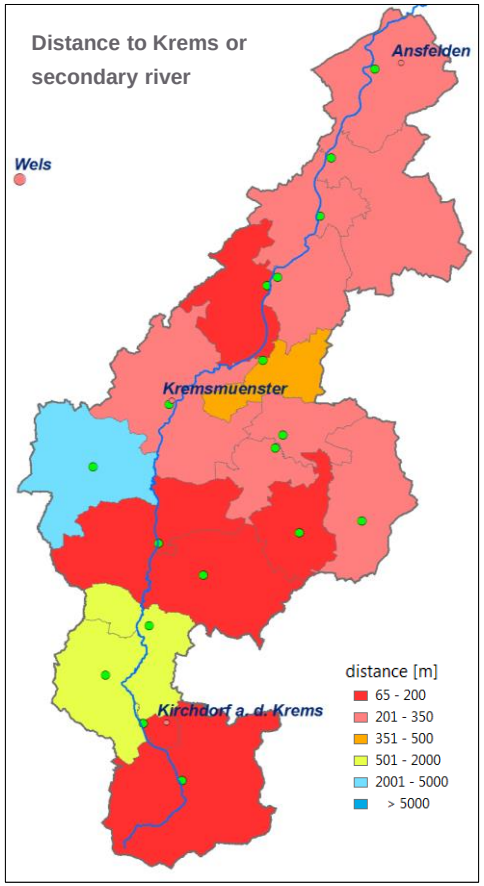


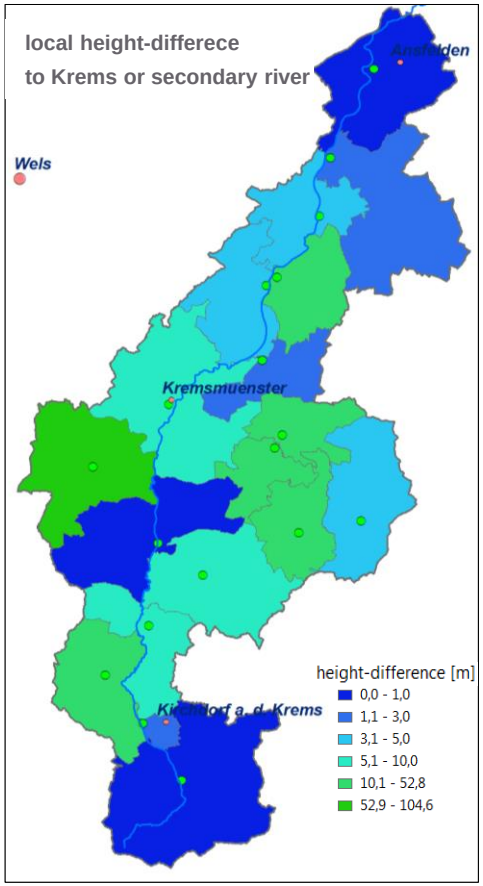


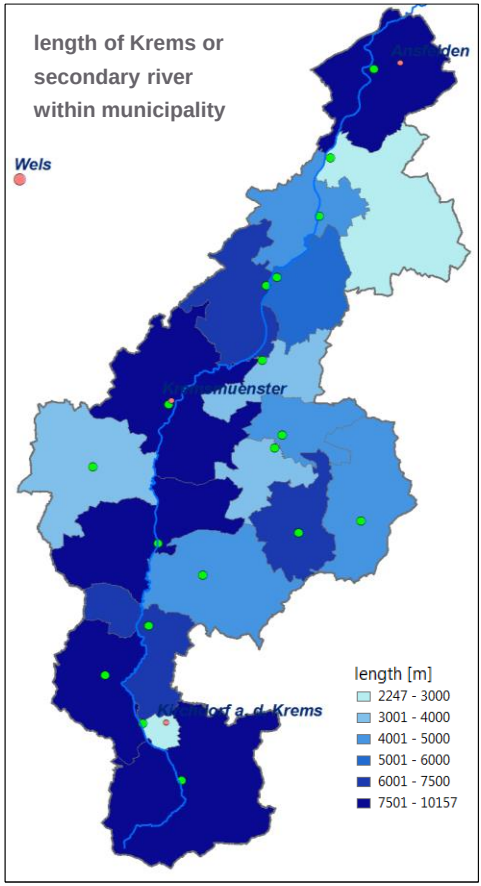
Geospatial data aqcuisition – selected data for statistical analysis explaining spatial impact on damage costs

→ Example: Kremstal catchment









Statistical Analysis explaining space-related effects and adaptation cost effects on damage repair costs

(Expenditures for road & flood protection system repair and construction)

Explanatory variables for damage repair expenditures

- elevation distance - valley floor to potentially exposed settlement area
- distance - valley floor to potentially exposed settlement area
- river length within municipality
- flood plane area within municipality
- potentially exposed settlement area
- potentially exposed road length
- Expenditures for
  - Flood protection measure implementation in municipality
  - Flood protection measure implementation in upstream municipalities (in distance categories)
  - Flood protection measure implementation covered by water management communities **new**
  - Flood protection measure implementation in downstream municipalities

Budget data compilation to relate damage repair costs to upstream adaptation costs – Example Krems catchment

(costs 2004-2012 by budget units roads and water management)

Road construction/repair costs related to municipality area,
flood protection repair /adaptation costs related to river length in municipality
(upstream costs aggregated to distance classes: 0km=municipality, >0-10km, 10-20km, 20-30km,<40km)

LAU_CODE	Municip	repair_pct_road	c_ar_road_0km	c_ar_road_10km	c_ar_road_20km	c_ar_road_30km	c_ar_road_40km	repair_pct_water	clen:_Water_all	clen_water_0km	clen_water_10km	clen_water_20km	clen_water_30km	clen_water_40km
40908	Micheldorf in Oberösterreich	-37,89	118,9	0	0	0	0	-8,67	20,4	20,4	0	0	0	0
40905	Kirchdorf an der Krems	-20,37	3923,5	118,9	0	0	0	2504,59	463,4	443,0	20,4	0	0	0
40904	Inzersdorf im Kremstal	11,68	118,3	4042,4	0	0	0	167,68	472,3	8,9	463,4	0	0	0
40917	Schlierbach	4,74	469,8	4160,7	0	0	0	771,84	497,5	25,2	472,3	0	0	0
40910	Nußbach	46,93	94,7	4511,6	118,9	0	0	160,74	525,0	27,5	477,1	20,4	0	0
40922	Wartberg an der Krems	-35,78	190,1	4606,3	118,9	0	0	-90,63	604,3	79,3	504,6	20,4	0	0
40913	Ried im Traunkreis	45,53	148,5	754,6	4160,7	0	0	22,91	609,6	5,3	132	472,3	0	0
40907	Kremsmünster	-59,40	627,8	433,3	4630,5	0	0	209,25	631,1	21,5	112,1	497,5	0	0
41009	Kematen an der Krems	-21,67	195,0	627,8	903,1	4160,7	0	67,96	686,7	55,6	21,5	137,3	472,3	0
41513	Rohr im Kremstal	145,58	206,8	822,8	4944,9	118,9	0	543,98	708,9	22,2	77,1	589,2	20,4	0
41518	Waldneukirchen	41,28	118,2	301,5	5791,9	0	0	381,69	713,4	4,5	49,7	659,2	0	0
41501	Adlwang	23,02	208,3	1707,4	4504,2	0	0	0,00	717,2	3,8	180,2	533,2	0	0
41511	Pfarrkirchen bei Bad Hall	-54,65	260,1	1789,4	4630,5	0	0	588,42	732,3	15,1	219,7	497,5	0	0
41503	Bad Hall	4,39	859,7	2049,5	4630,5	0	0	-19,67	736,9	4,6	234,8	497,5	0	0
41018	Piberbach	-39,58	259,4	2149,4	1229,6	4160,7	0	-36,59	752,4	15,5	119	145,6	472,3	0
41014	Neuhofen an der Krems	304,77	327,1	661,2	2507,4	4630,5	0	-68,14	793,3	40,9	93,3	161,6	497,5	0
41020	Sankt Marien	-35,01	236,4	781,5	2280,9	1021,4	4042,4	4246,13	818,8	25,5	112	71,7	146,2	463,4
41002	Ansfelden	8,48	750,6	563,5	1520,9	1647,7	4630,5	8762,44	1353,3	534,5	66,4	97,9	157	497,5

Statistical analysis relating space effects against damage repair costs (preliminary, Krems catchment)

(roads, flood protection)

Pearson Correlation Matrix

	COST_ROAD_2013	REPAIR_PCT_ROAD	COST_WATER_2013	REPAIR_PCT_WATE-R
PCT_AREA_FLOODED	0.861	0.442	0.710	0.693
DIST_TO_KREMS	-0.233	0.107	-0.249	-0.214
HIGHT_TO_KREMS	-0.253	0.088	-0.389	-0.275
CLEN__WATER_ALL	0.760	0.076	0.556	0.873
CLEN_WATER_0KM	0.701	-0.037	0.803	0.875
CLEN_WATER_10KM	-0.450	-0.115	-0.006	-0.325
CLEN_WATER_20KM	0.228	-0.017	-0.318	-0.169
CLEN_WATER_30KM	0.166	0.381	-0.023	-0.046
CLEN_WATER_40KM	0.468	-0.165	0.388	0.941

1st test-results for Krems Catchment

(incomplete cost data – water management community data are lacking)

- Statistical relations of repair costs/per spatial entity against spatial characteristics are plausible, but only some show higher significance
- Statistical relations of repair costs/per spatial entity against adaptation costs
- Costs of upstream adaptation show some significance.

Statistical analysis relating space effects against damage repair costs (preliminary, Krems catchment)

(roads, flood protection)

▼OLS Regression

58 case(s) are deleted due to missing data.

Dependent Variable	REPAIR_PCT_ROAD
N	11
Multiple R	0.529
Squared Multiple R	0.280
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	101.766

Regression Coefficients $B = (X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-61.019	60.499	0.000	.	-1.009	0.347
PCT_AREA_FLOODED	9.121	5.667	0.566	0.831	1.609	0.152
DIST_TO_KREMS	0.005	0.096	0.057	0.098	0.055	0.957
HIGHT_TO_KREMS	0.825	3.302	0.261	0.094	0.250	0.810

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	28133.739	3	9377.913	0.906	0.485
Residual	72493.764	7	10356.252		

▼OLS Regression

58 case(s) are deleted due to missing data.

Dependent Variable	REPAIR_PCT_WATE-R
N	11
Multiple R	0.698
Squared Multiple R	0.487
Adjusted Squared Multiple R	0.267
Standard Error of Estimate	2377.760

Regression Coefficients $B = (X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-860.228	1413.564	0.000	.	-0.609	0.562
PCT_AREA_FLOODED	305.558	132.415	0.685	0.831	2.308	0.054
DIST_TO_KREMS	0.668	2.243	0.257	0.098	0.298	0.774
HIGHT_TO_KREMS	-21.377	77.149	-0.244	0.094	-0.277	0.790

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	37580572.784	3	12526857.595	2.216	0.174
Residual	39576200.995	7	5653742.999		

1st test-results for Krems Catchment

(incomplete cost data – water management community data are lacking)

Statistical analysis relating space effects and adaptation costs against damage repair costs (preliminary, Krems catchment)

(roads, flood protection)

▼OLS Regression

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Dependent Variable	REPAIR_PCT_ROAD
N	11
Multiple R	0.957
Squared Multiple R	0.917
Adjusted Squared Multiple R	0.584
Standard Error of Estimate	64.721

Regression Coefficients B = $(X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-395.319	337.459	0.000	.	-1.171	0.362
PCT_AREA_FLOODED	27.734	7.832	1.722	0.176	3.541	0.071
DIST_TO_KREMS	-0.001	0.084	-0.011	0.052	-0.013	0.991
HIGHT_TO_KREMS	1.515	2.990	0.480	0.046	0.507	0.663
CLEN_WATER_0KM	-0.866	0.326	-1.325	0.168	-2.660	0.117
CLEN_WATER_10KM	0.582	0.692	1.143	0.023	0.842	0.489
CLEN_WATER_20KM	0.349	0.550	0.614	0.044	0.634	0.591
CLEN_WATER_30KM	0.356	0.464	0.764	0.042	0.768	0.523
CLEN_WATER_40KM	0.263	0.371	0.511	0.080	0.710	0.551

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	92249.871	8	11531.234	2.753	0.294
Residual	8377.631	2	4188.816		

▼OLS Regression

58 case(s) are deleted due to missing data.

Dependent Variable	REPAIR_PCT_WATE-R
N	11
Multiple R	0.995
Squared Multiple R	0.990
Adjusted Squared Multiple R	0.952
Standard Error of Estimate	606.199

Regression Coefficients B = $(X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	1596.760	3160.749	0.000	.	0.505	0.664
PCT_AREA_FLOODED	32.448	73.356	0.073	0.176	0.442	0.701
DIST_TO_KREMS	0.004	0.783	0.002	0.052	0.005	0.996
HIGHT_TO_KREMS	1.305	28.010	0.015	0.046	0.047	0.967
CLEN_WATER_0KM	6.797	3.049	0.375	0.168	2.229	0.156
CLEN_WATER_10KM	-3.594	6.477	-0.255	0.023	-0.555	0.635
CLEN_WATER_20KM	-2.702	5.152	-0.172	0.044	-0.525	0.652
CLEN_WATER_30KM	-3.047	4.346	-0.236	0.042	-0.701	0.556
CLEN_WATER_40KM	7.482	3.476	0.524	0.080	2.153	0.164

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	76421819.595	8	9552727.449	25.995	0.038
Residual	734954.184	2	367477.092		

1st test-results for Krems Catchment

(incomplete cost data – water management community data are lacking)

Tasks carried out

- Extreme events exploration:
  - heavy precipitation events, floods 2002 – 2013
- Delineation of study area: rivers, catchments, municipalities
- Budget analysis 2002-2014 of all (153) municipalities in the study catchments
- Geospatial data acqusition, compilation, analysis, of risk exposure
- Statistical analysis of damage repair costs and change of costs
  - versus
    - physical characteristics and
    - adaptation costs during the years between heavy extreme events
- Case studies: interviews in selected municipalities to gain deeper insights
  - on damage, adaptation and costs of local, upstream and downstream measures,
  - on institutional instruments to share risk and costs
- Estimate adaptation /maladaptation impact of extreme events during future climate

Case studies to examine deeper insights (by municipality / catchment)

- Interviews with
  - municipality representatives and
  - water community representatives
  - province representatives on:
    - extreme flood events
    - damage and damage repair costs
    - upstream/downstréam adaptation measures and costs
    - adaptation measures and costs covered by water management communities
    - mechanisms and effects of water management communities for sharing risk and costs

Case study interviews with Steyr, Schwertberg, Ansfelden

(1st round)

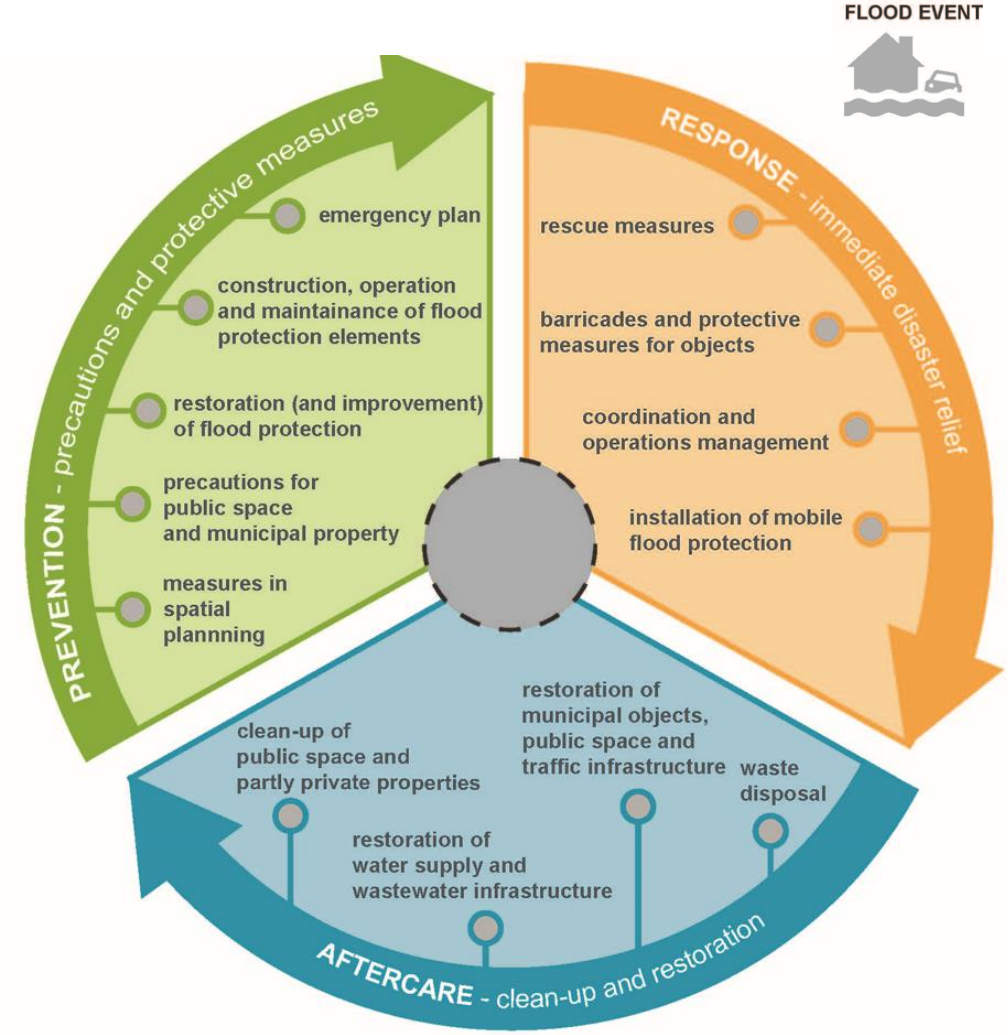
Interview-Leitfaden kurz

1. Schäden infolge von Hochwasserereignissen zwischen 2002 und 2014 und Schutzmaßnahmen
2. Aufgaben der Gemeinde bei der BEWALTIGUNG und der NACHSORGE von Hochwasserereignissen
3. Rolle der Gemeinden bei PRAVENTION – Umsetzung/Finanzierung
4. Kosten der Gemeinde im Zeitraum 2002-2014 durch Hochwasser und Schutz (BEWALTIGUNG, NACHSORGE PRAVENTION)
5. Zusammenarbeit in bzw. mit Gemeindeverbänden und finanzielle Regelung (Aufteilung der Kosten, Datenverfügbarkeit)
6. Einschätzung der Wirksamkeit von Hochwasserschutzmaßnahmen
7. Unterstützung durch Katastrophenfonds und Land OO?
8. Welche Förderungen für Private für Hochwasserschutzes gibt es, Beträge?

2	Fahrt nach Steyr
3	Erster Termin in Steyr Bei Dienststellenleiter DI Ernst Peter Richter
	Fahrt nach Schwertberg
3	Zweiter Termin in Schwertberg Bei Amtsleiter Markus Brandstetter BA
8	Fahrt nach Ansfelden
9	Mittagspause in Ansfelden + Verfassen der ersten beiden Interviewprotokolle
9	Dritter Termin in Ansfelden Bei Stadtamtsdirektor Dr. Wilhelm Wilfinger

Selected interview findings:

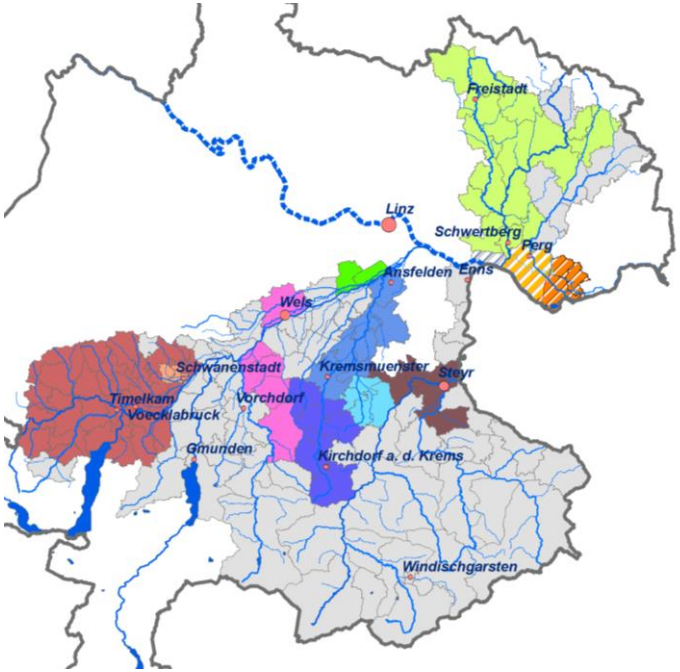
Main responsibilities: damage mitigation (response, aftercare)
adaptation: prevention



Selected interview findings

Flood related costs (damage repair and adaptation) to some extent covered by water management communities

- Flood protection is a cross-sectional task – difficult to identify in municipal budgets
- different institutional framework conditions and accounting practices hinder comparability
- expenditures in small municipalities are not only covered by municipalities
- water management communities share risks and costs in several (sub-)catchments.



- WV Bezirk Vöcklabruck, Hochwasserschutz Großraum Schwanenstadt (3)
- WV Bezirk Vöcklabruck (32)
- WV Haidbach (2 + Linz)
- WV Oberes Kremstal (7)
- WV Unteres Kremstal (7)
- WV Kurbezirk Bad Hall (4)
- WV Pettenbachrinne (5)
- WV Steyr_Kruglwehr (3)
- WV Aist (18)
- WV Aist Donau-Machland (1)
- WV Aist, Machland (1)
- WV Aist, Machland, Donau-Machland (1)
- WV Machland, Donau-Machland (3)
- not member of any (66)

Tasks carried out

- Extreme events exploration:
  - heavy precipitation events, floods 2002 – 2013
- Delineation of study area: rivers, catchments, municipalities
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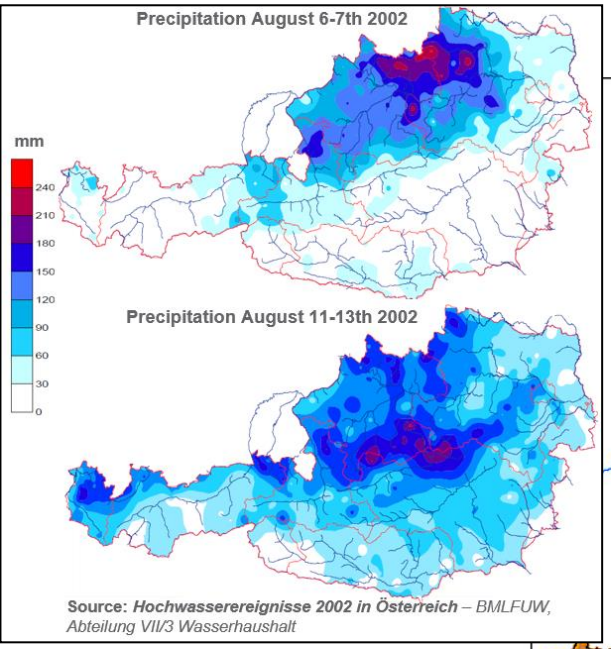
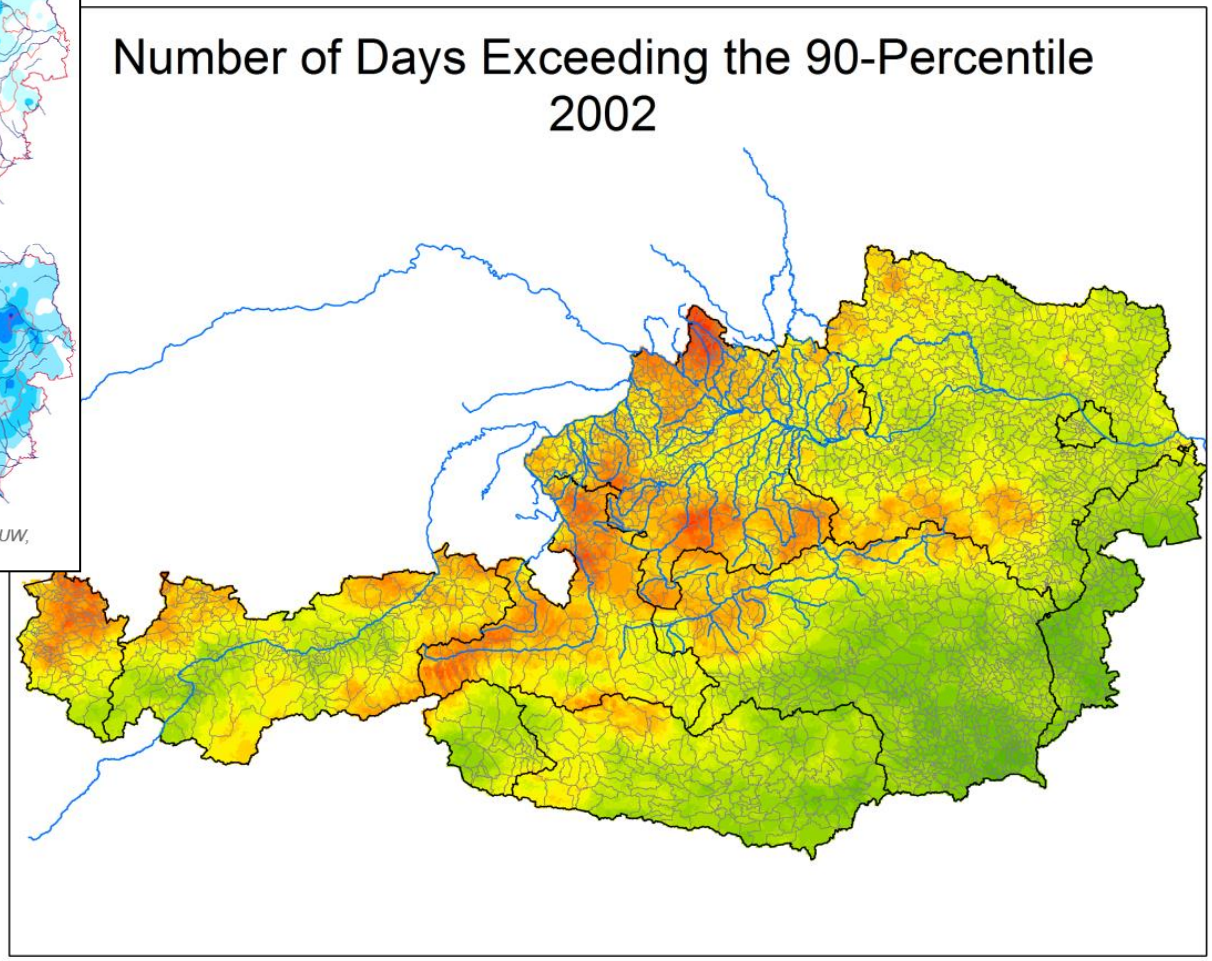
Exploring potential future climate impact on damage repair costs

- Analysis current climate versus future climate
  - ÖSK15 layer data extracted
    - heavy precipitation days 2060 - 2010 – 2030 – 2050
  - Differences of heavy precipitation days between current and future climate arte extracted (first explorations carried out untill now)
  - Relative differences will serve as change ratio to estimate future damage repair costs without additional measures and discuss savings through adaptation

Modelled extreme precipitation event days 2002

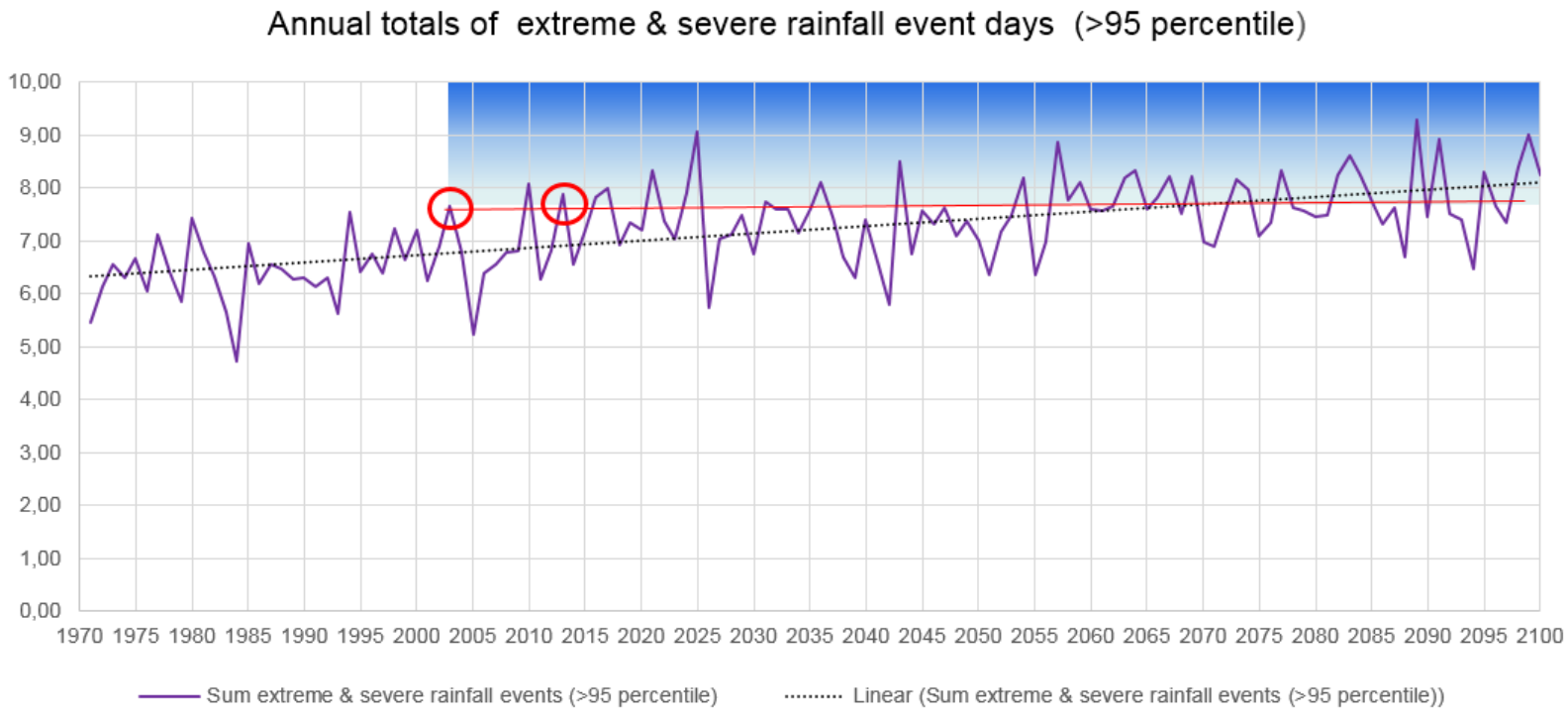




Source ÖKS15 data –
number of days with more precipitation than on 90% of the observed days.

Modelled days with extreme and severe rainfall events

(OÖ observation: 1971-2010, projection 2011-2100 (RPC 4.5))



Data: ÖKS15, Scenario: RCP 4,5

First conclusions

- Budgets reflect extreme event damage repair and adaptation to some extent
  - Flood protection is a cross-sectional task – difficult to identify in municipal budgets
  - Distinction of expenditures for coping, aftercare and prevention is uncertain but possible in a coarse way through the temporal sequence of expenditures related to event occurrence
  - Expenditures in small municipalities are not only covered by municipalities themselves
- Water management communities are established in selected catchments
  - They share risks and costs.
  - Data acquisition from water management communities needs an agreement of the data protection commission (expected in June 2017)
- Distinct statistical relations can be observed:
  - between damage repair costs and spatial characteristics,
  - between damage repair costs and adaptation costs.
  - The significance of explanatory model results is higher by including adaptation costs.
  - Effects on repair costs through upstream adaptation could be identified.
- Statistical analysis must be repeated with merged expenditure data
- Expected increase of extreme events confirmed through frequency indicators from recent climate simulations

(Examination with completed expenditure data will be carried during summer)

AIT Austrian Institute of Technology

Thank you for attention!

Wolfgang Loibl

Sustainable Buildings and Cities
Center of Energy
wolfgang.loibl@ait.ac.at