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Use of flood forecasting in reducing flood risk in an agricultural area

D. Carillo-Herrera[a], M. Werner [a,b]

[a] Deparment of Water Engineering, UNESCO-IHE, PO Box 3015, 2601DA, Delft, The Netherlands,
(carri4@unesco-ihe.org, m.werner@unesco-ihe.org)

[c] Operational Watermanagement, Deltares, Delft, The Netherlands
(micha.werner@deltares.nl)

Introduction

- Flood forecasting & warning often “targeted” at urban areas
- Developing countries → Agricultural based economies
- Local produce important for food provision to nearby cities
- Rural/Agricultural areas →farmers often living in the area, small farming communities
- Generally rural communities are poor → high vulnerability

Measures for reducing flood risk

Structural e.g. dykes

- Separation of areas with high areas from flooding – e.g urban
- Risk reduction through changing hazard → Impact on river corridor; reduced space for rivers;

Non-structural e.g. flood warning

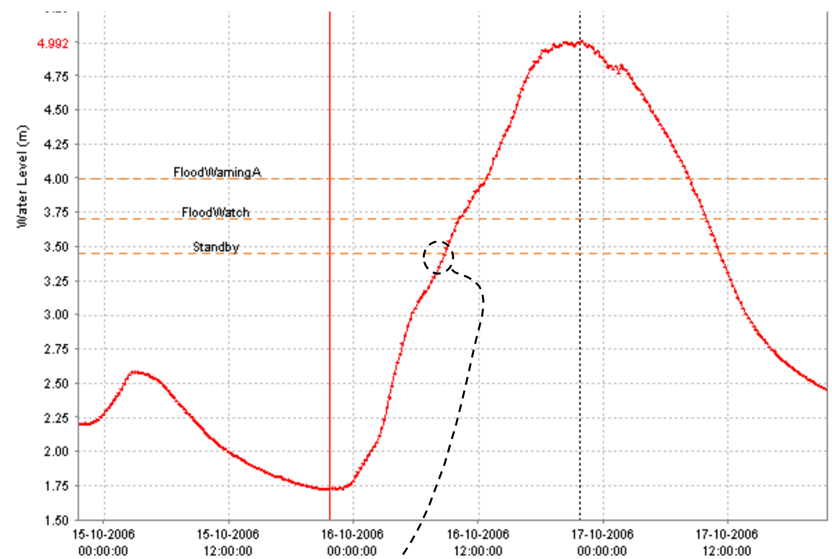
- Advance warning of imminent flood → response
- Risk reduction through changing vulnerability
- In principle no impact on flood event

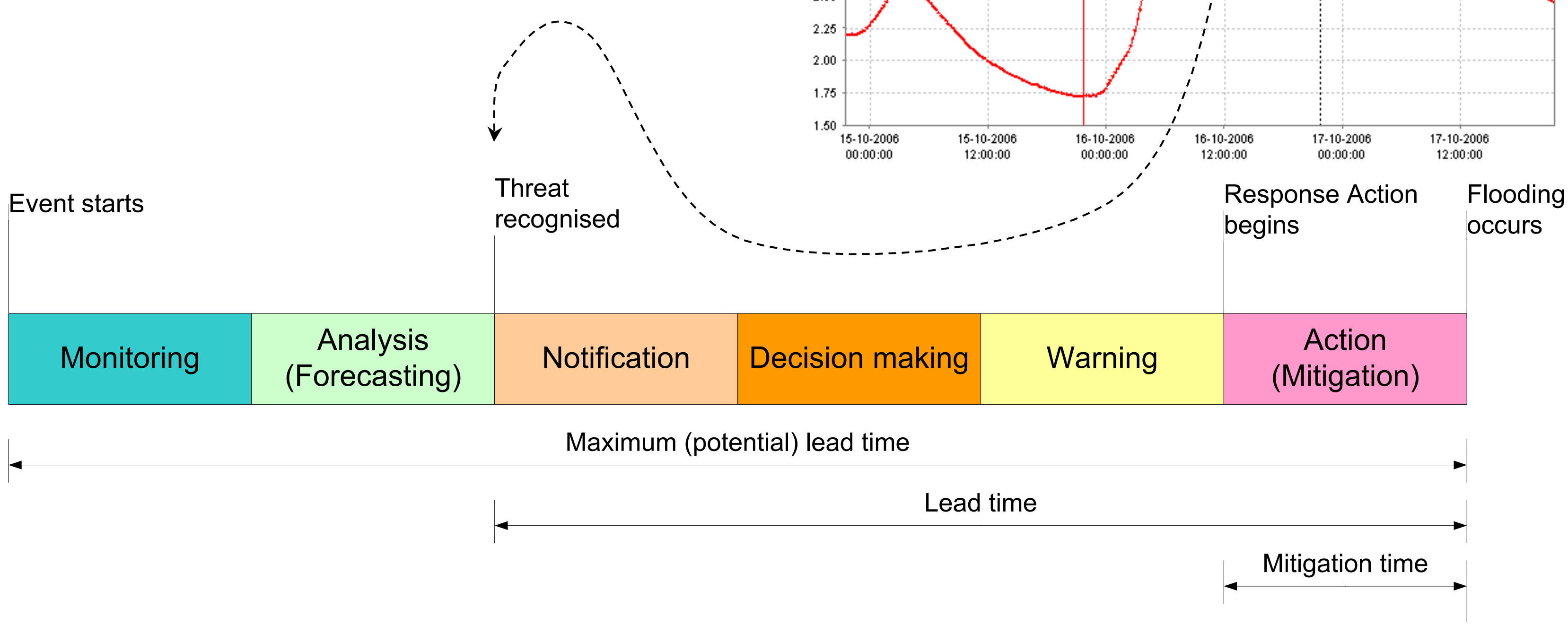
How can flood forecasting & warning contribute to reducing flood risk??

Forecasting, warning and response timeline

Flood forecasting, warning & response

- Action after decision to warn
- Decision taken e.g. on threshold crossing
  → " event"





Assessing skill of forecasts

Understanding forecast reliability

- 2x2 Contingency table common tool in assessing how well a forecast performs in predicting the "event"
- Combination of skill scores to understand different aspects of forecast reliability

		Observed Event	
		Yes	No
Forecast Event	Yes	**Hit (a)**	**False Alarm (b)**
	No	**Miss (c)**	**Correct Negative (d)**

$$POD = \frac{a}{a+c}$$

$$FAR = \frac{b}{a+b}$$

$$B = \frac{a+b}{a+c}$$

$$TS = CSI = \frac{a}{a+b+c}$$

etc.....

Assessing value of forecasts

- Objective is to reduce flood risk through reducing consequence or loss
- Total flood losses divided into two parts
  - Losses that can be avoided by taking mitigation response
  - Losses that cannot be avoided through mitigation

		Observed Event	
		Yes	No
Forecast Event	Yes	Total loss $L_A + C_R + C_F$	Total loss $C_R + C_F$
	No	Total loss $L_U + L_A + C_F$	Total loss C_F

L_A : Avoidable Losses

L_U : Unavoidable Losses

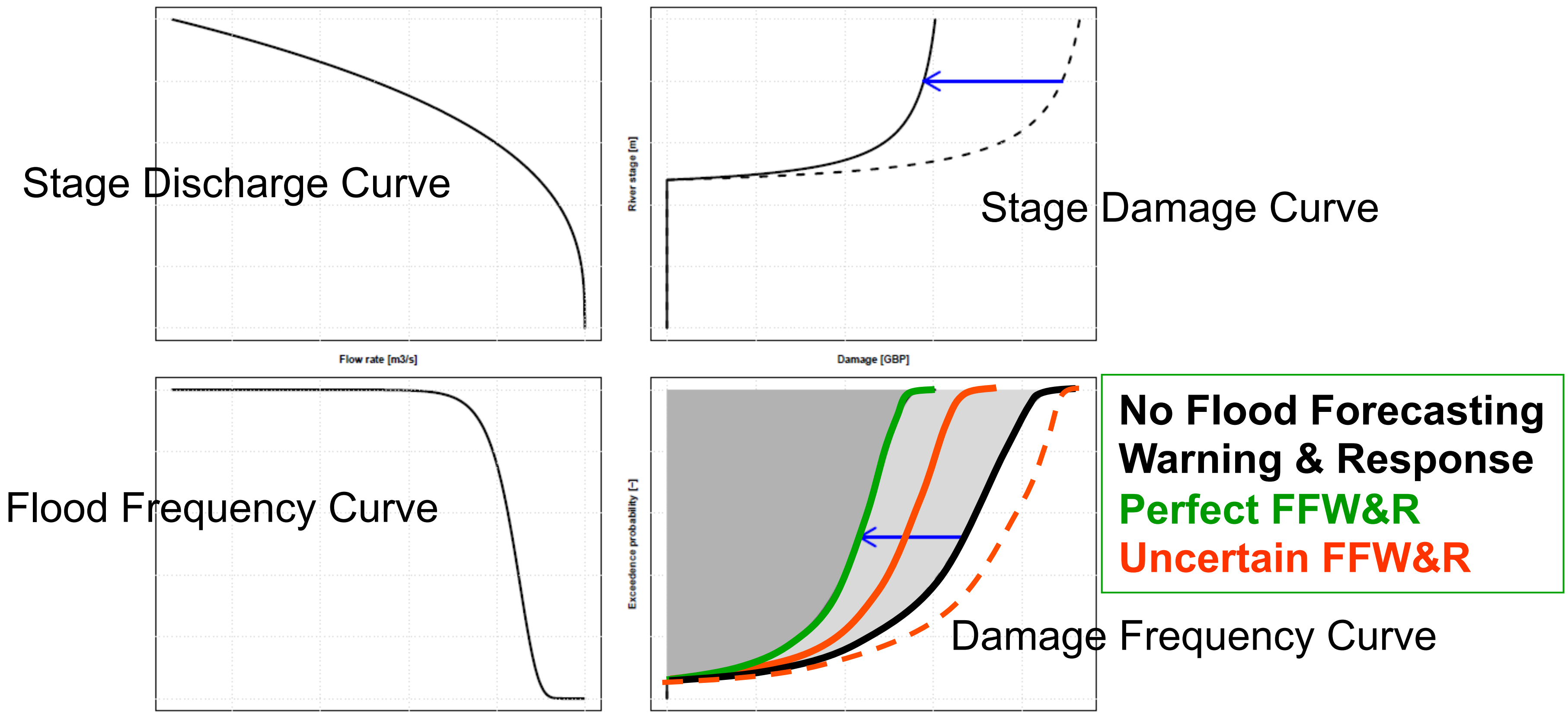
C_R : Cost of response

C_F : Cost of forecasting

$$Cost - Loss\ ratio = \frac{C_R}{L_A}$$

Translating this to flood risk

Hydro-Economic Expected Annual Damage Model



From Verkade & Werner, 2011

$$FloodRisk = \int_0^1 p(E)D(E)dp$$

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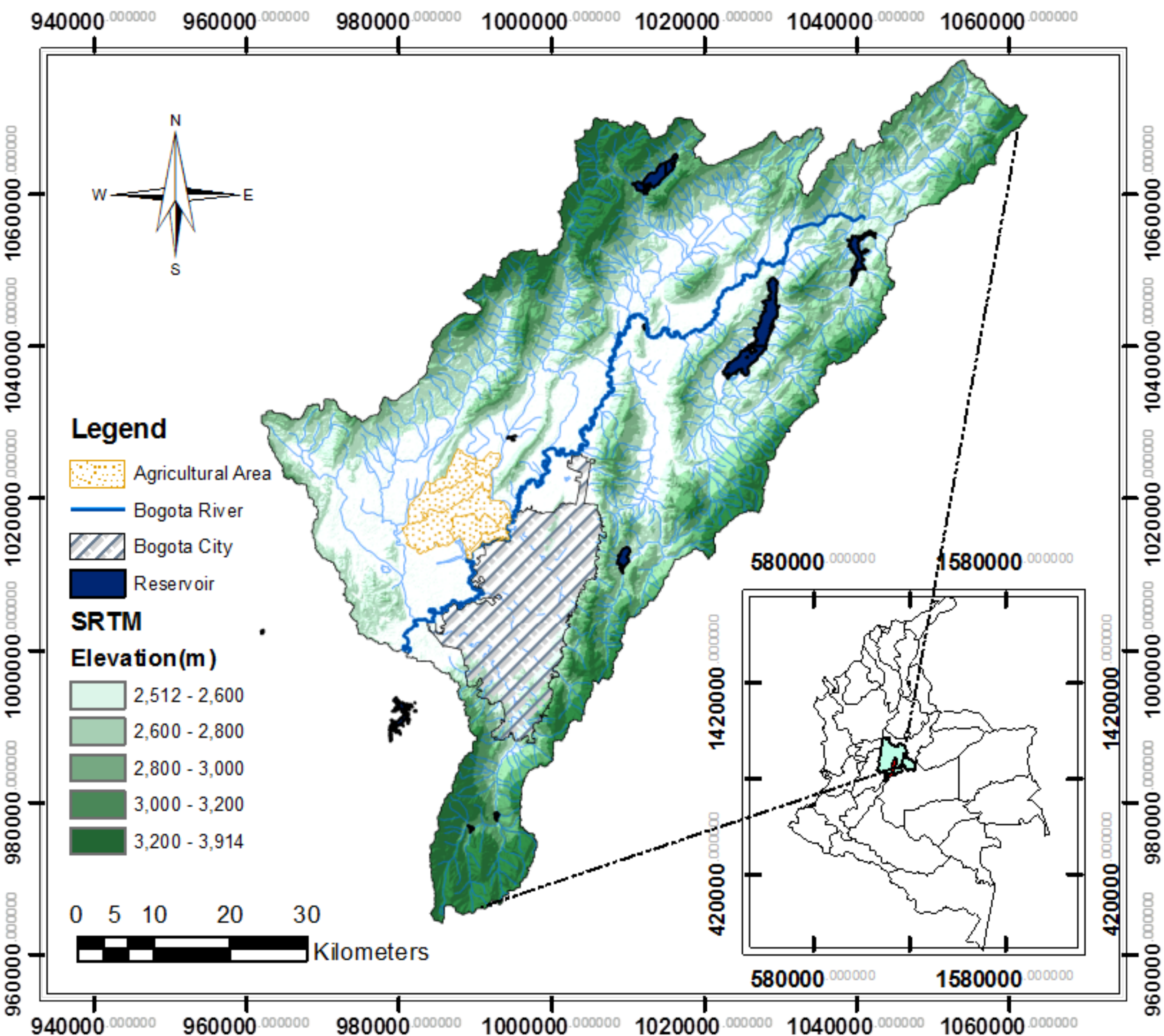
Case Study Area
Ramada Agriculture district, Bogotá, Colombia



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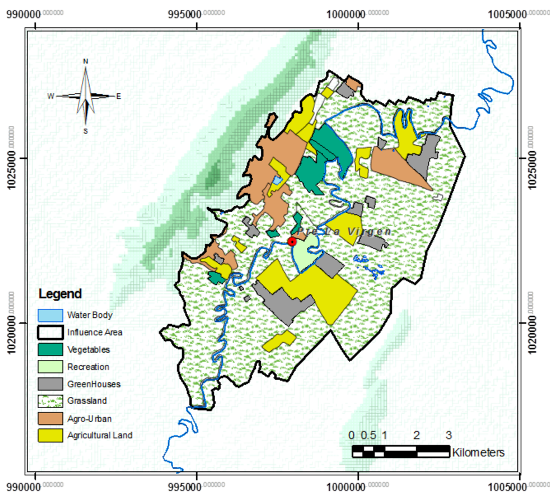
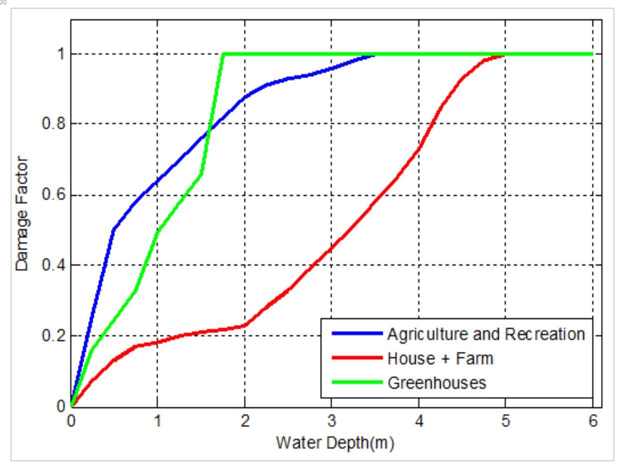
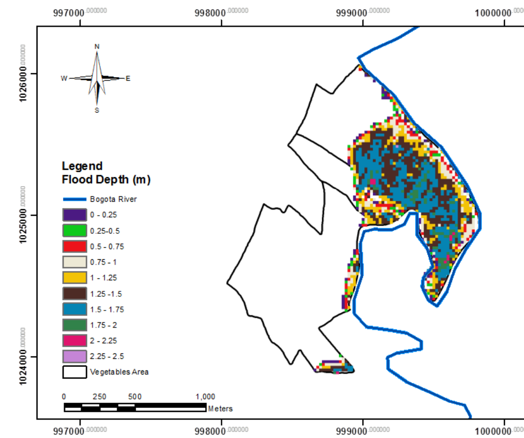


Land use map of district



Depth-Damage curves



Flood depth for flood with return period T

Land Use type	Total Area (ha)	Total Area (%)	Expected Damage T=25 years			Expected Damage T=50 years			Expected Damage T=100 years		
			Area (ha)	Area (%)	Damage (M€)*	Area (ha)	Area (%)	Damage (M€)*	Area (ha)	Area (%)	Damage (M€)*
Agricultural Land	633.5	11.6%	55.0	1.01%	€ 1.60	63.5	1.16%	€ 2.15	69.4	1.27%	€ 2.62
Vegetables	202.6	3.7%	67.9	1.24%	€ 1.75	72.7	1.33%	€ 2.19	75.4	1.38%	€ 2.49
Agro - Urban Mosaic	503.6	9.2%	2.1	0.04%	€ 0.08	3.8	0.07%	€ 0.18	5.1	0.09%	€ 0.29
Grassland	3661.7	67.1%	961.6	17.62%	€ 12.95	1001.1	18.34%	€ 14.74	1048.3	19.21%	€ 16.20
Greenhouses	296.2	5.4%	7.0	0.13%	€ 1.39	8.9	0.16%	€ 2.15	9.8	0.18%	€ 2.41
Recreational Land	62.0	1.1%	60.2	1.10%	€ 3.73	60.8	1.11%	€ 4.10	61.2	1.12%	€ 4.33
Water Bodies	98.8	1.8%	-	-	-	-	-	-	-	-	-
Total	5458.3	100.0%	1153.7	21.1%	€ 21.52	1210.7	22.2%	€ 25.50	1269.2	23.3%	€ 28.34

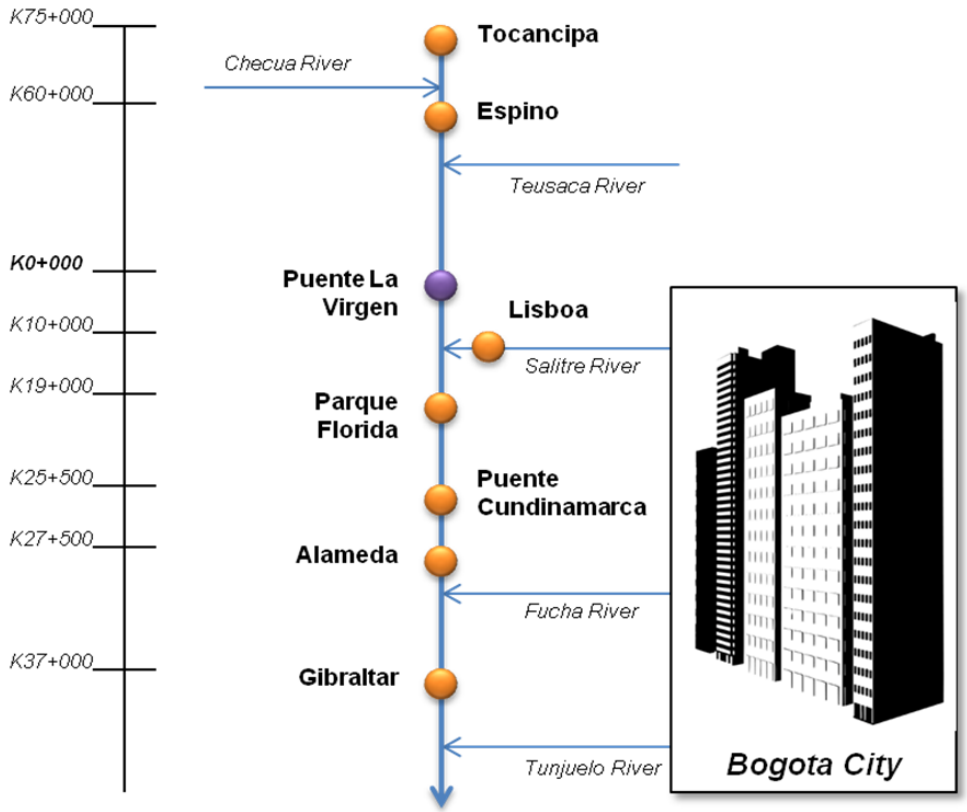
*Damage based on a year 2012 index

Damage-Frequency Curve

Provision of forecasts for the Ramada district

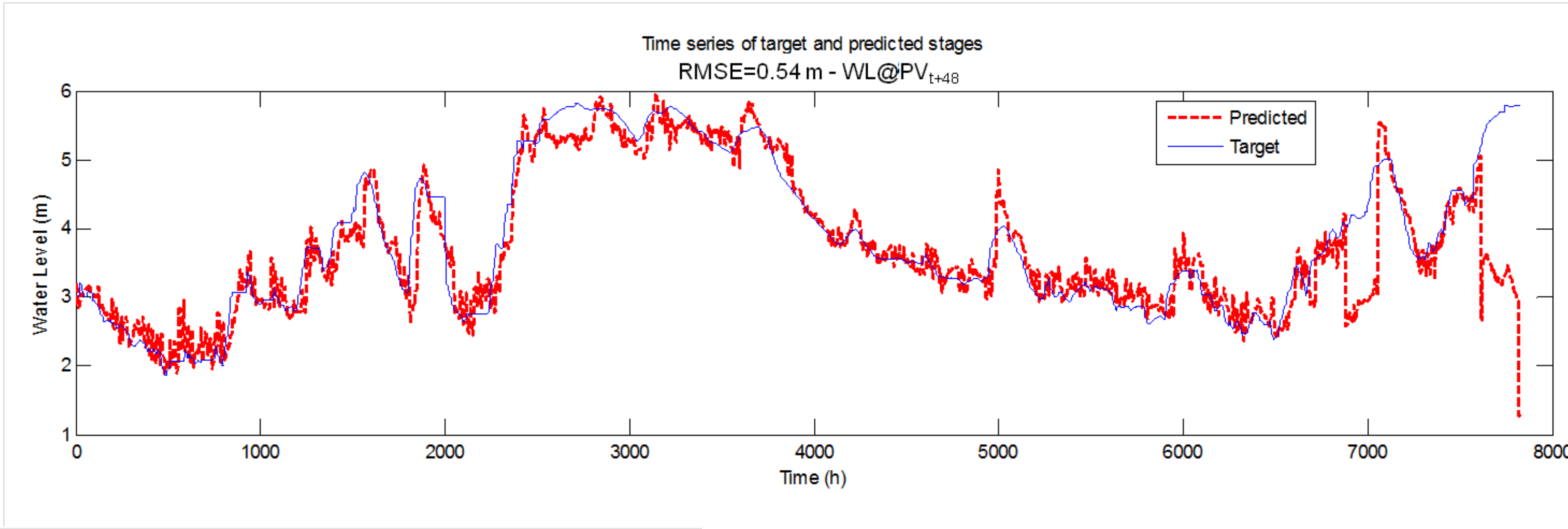
Simple regression model from u/s gauges

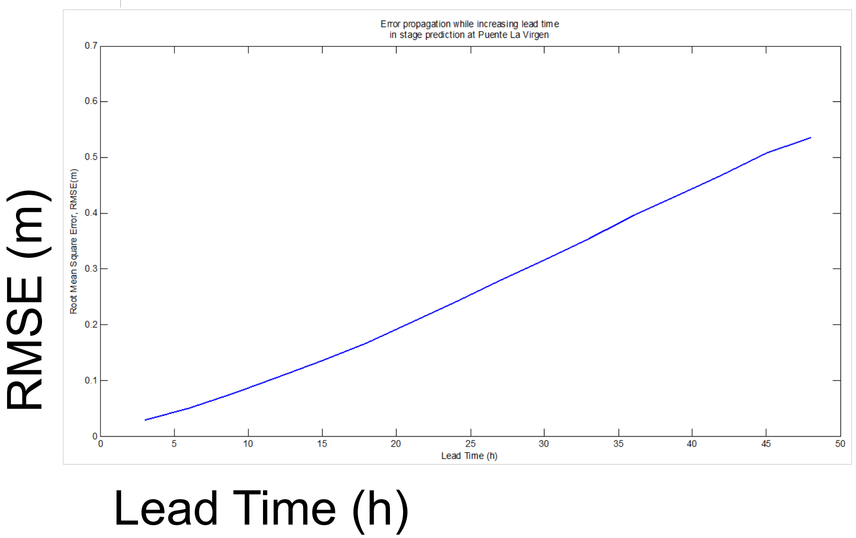
$$
\begin{aligned}
WL@PV_{t+n} = {} & b_0 + b_1 WL@T_{t-0} + b_2 WL@T_{t-k1} + b_3 WL@E_{t-0} + b_4 WL@E_{t-k2} \\
& + b_5 WL@PV_{t-0} + b_6 WL@L_{t-0} + b_7 WL@L_{t-k3} + b_8 WL@PF_{t-0} \\
& + + b_9 WL@PF_{t-k4} + b_{10} WL@PC_{t-0} + b_{11} WL@PC_{t-k5} + b_{12} WL@A_{t-0} \\
& + b_{13} WL@A_{t-k6} + b_{14} WL@G_{t-0} + b_{15} WL@G_{t-k7}
\end{aligned}
$$

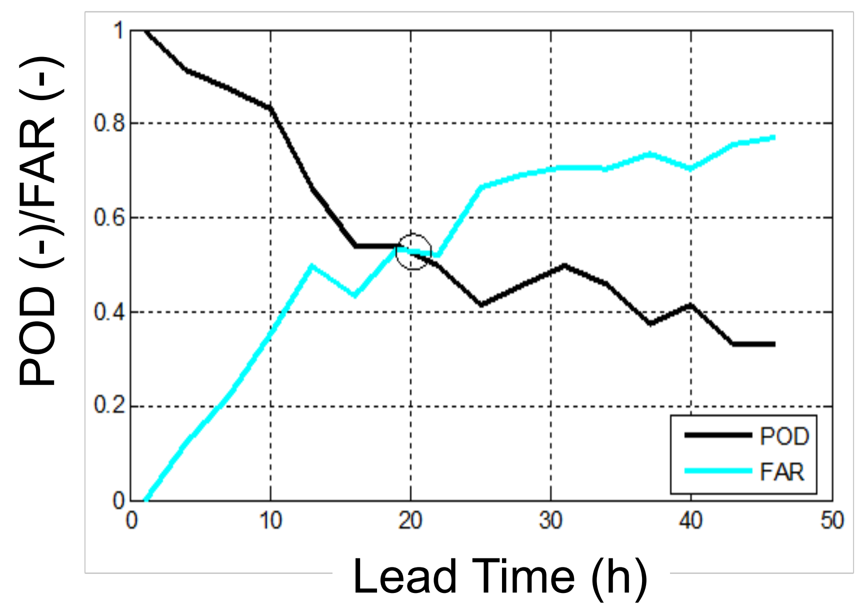


Station	Average lag (h)
Tocancipa	68
Espino	40
Lisboa (tributary)	10
Pq Florida	10
Pte Cundinamarca	11
Alameda	10
Gibraltar	16

Skill of forecasts for the Ramada district

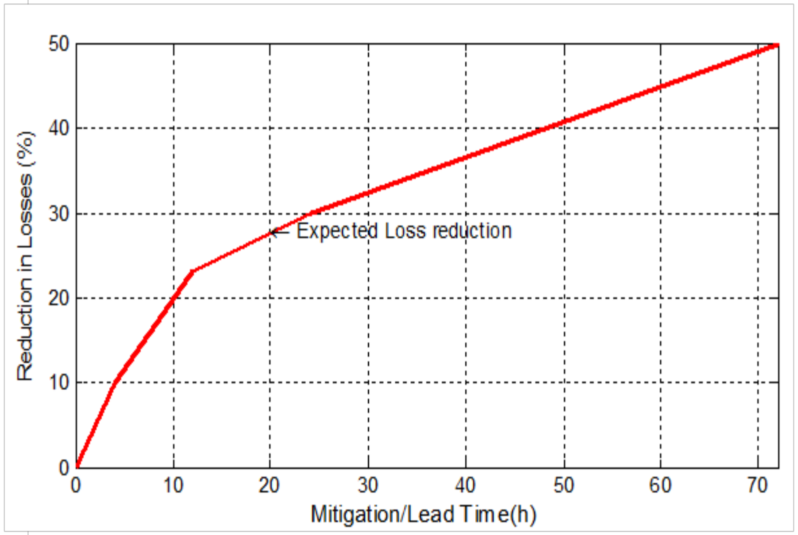






Measures for reducing damage following a warning

Land Use type	Main Damage	Possible Mitigation Action	Time Required (h)
Agricultural Land and Vegetables	Crop Loss	Harvest if possible**	≧72
		De-energize and Lock up equipment	≧5
		Prepare Pumps if drainage available	≧2
Agro - Urban Mosaic	Assets damage	Evacuate People*	≧16
		Wall defence / sand bags installation***	≧24
		Raise house items (elevate from the ground level)	≧2
Grassland	Livestock dead / Milk Production Reduction	Livestock relocation	≧24
		Hay coverage	≧2
		Creation of Islands of safety	≧48
Greenhouses	Crop Loss	People Evacuation*	≧16
		Wall defence / sand bags installation***	≧24
		De-energize and Lock up equipment	≧5
Recreational Land	Turf damage	Wall defence / sand bags installation***	≧24
		De-energize and Lock up equipment	≧5
		People Evacuation*	≧16



Maximum % loss reduction in an agricultural area following a warning (Day, 1970)

Potential measures per type of agriculture & time required

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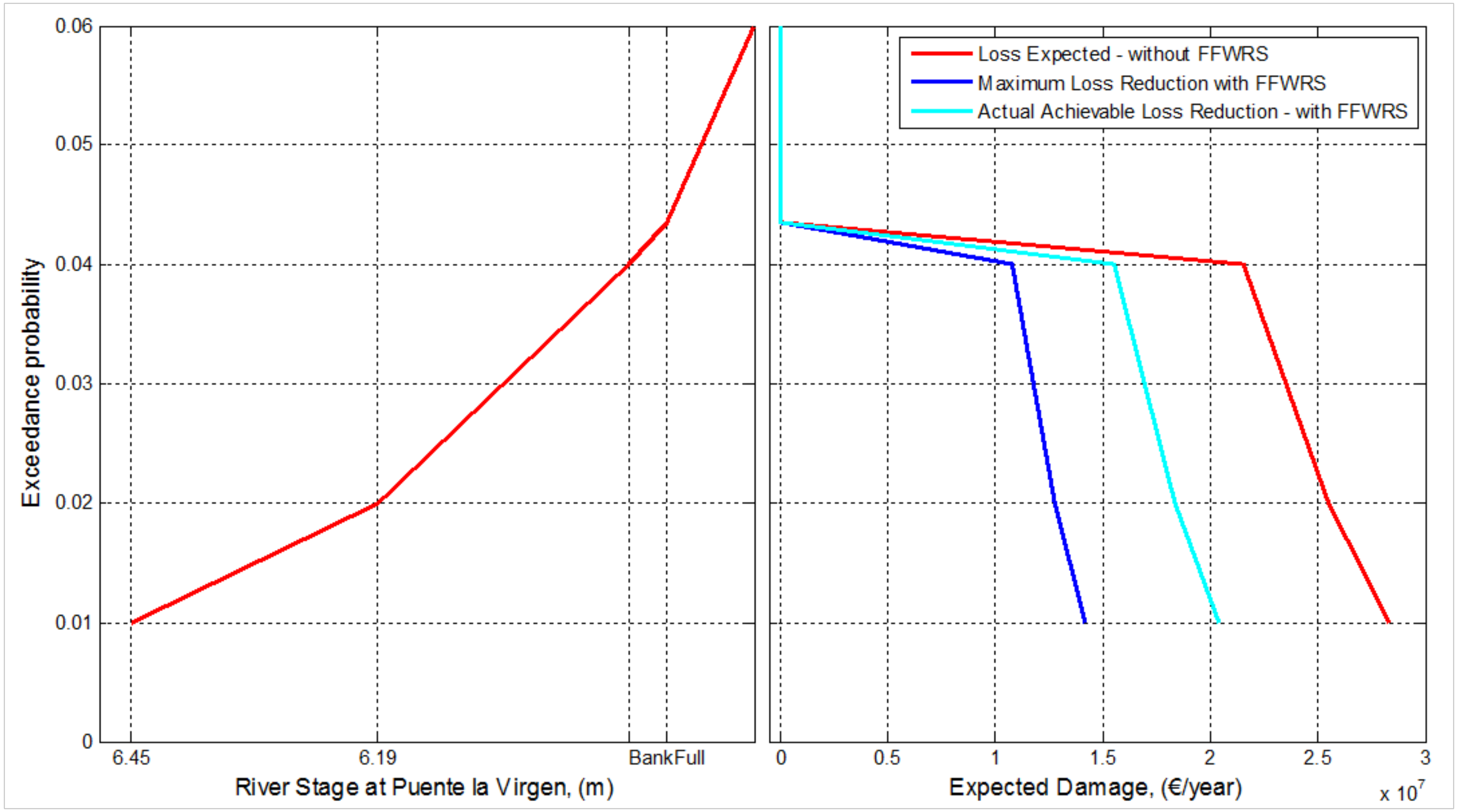
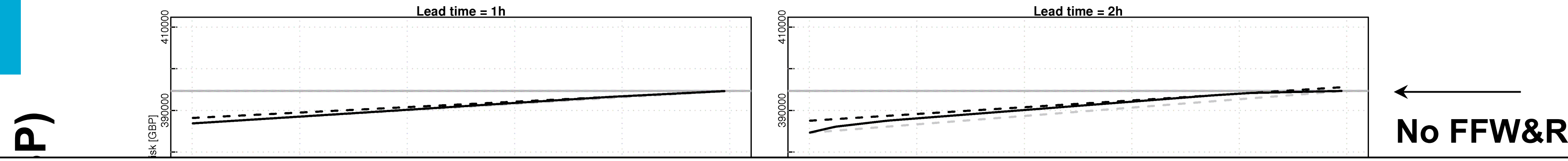
Reduction of EAD in the Ramada district



- EAD without flood warning service about 1 M Euro/year
- EAD with flood warning service about 0.76 M Euro/year
- → Benefit : 0.26 M Euro /year

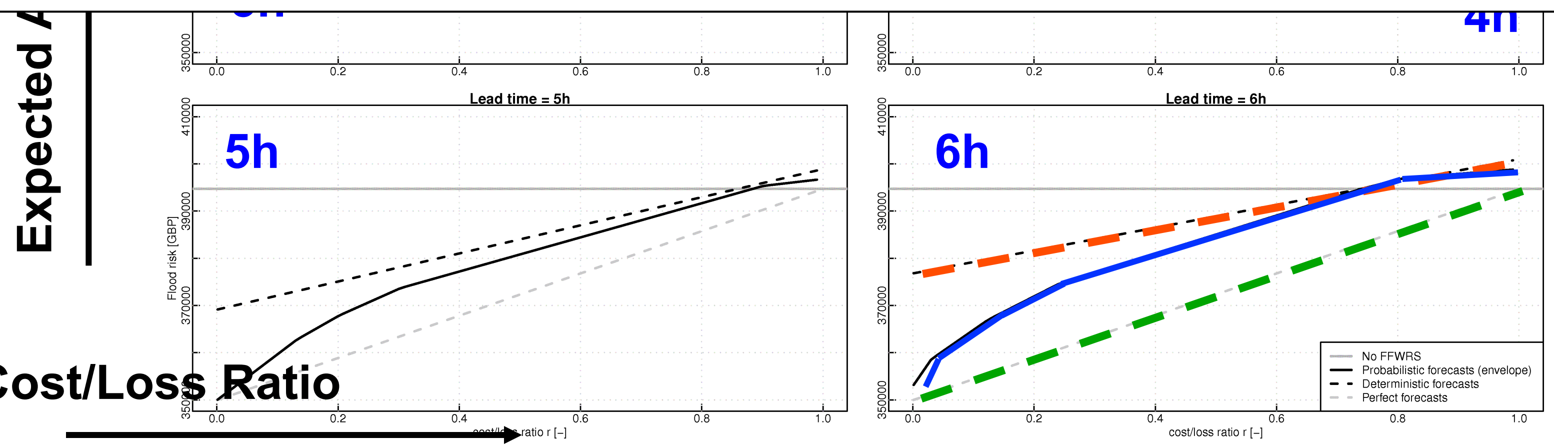
Reduction of flood risk

Perfect forecast, Deterministic Forecast, Probabilistic Forecast



Take home message:
Lead time that should be responded to depends on the user/type of response

In this case – for some users responding to forecasts with too long a lead time can **increase** flood risk



Verkade J. Werner M. 2011. Estimating the benefits of single value and probability forecasting for flood warning, *Hydrology and Earth System Sciences*, 15: 3751-3765

Discussion

- Approach allows assessing “value” of provision of flood forecasting and warnings
- Trade-off between structural and non-structural measures
  - Reducing flood risk using a mix of strategies – symbiosis of measures
  - Business case for reducing uncertainty in forecasting (gauging networks, radar, meteorological forecasting, hydrological forecasting, institutional arrangements)

Caveats, Assumptions and Challenges

- Case presented here based on several assumptions – economic data easy to find – but details such as depth-damage curves, response mechanisms, cost/loss ratios psychology of response difficult – “borrowed” from other countries

- Approach is “easy” for direct tangible impacts as presented – can be extended to indirect tangible impacts – but intangible impacts, loss of life, political & legal implications, social acceptance of warning etc. much more difficult

Thank you…

FORESEE

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