CONCEPTUALIZING HUMAN-FLOOD INTERACTIONS

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SEVENTH FRAMEWORK PROGRAMME

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UNESCO-IHE Institute for Water Education

thanks to: Guenter Bloeschl, Luigia Brandimarte, Gemma Carr, Jeltsje Kemerink, Michelle Kooy, Linda Kuil, Jose Salinas, Alberto Viglione

WE (HUMANS) ARE UNFAIR.

History


N51°
N49°
N47°
Vajont Dam, Italy
Prime Meridian
E 2°30'
E 7°30'
N45°
E 12°30'
E 17°30'
E 22°30'
N43°
N41°
N39°
Google

History

- Early 1960s, Italy
- Construction of the Vajont Dam (280m)

Vajont dam disaster

- 9 October 1963 at 22:39
- Giant wave raised by a landslide into this “brand new” hydroelectric reservoir
- The wave affected five towns, killing 1918 people

Longarone (BEFORE 9 October 1963*)*

Longarone (AFTER 9 October 1963*)*

An alternative story (a dream?)

An alternative story (a dream?)

- Late 1950s, Italy
- Roberto Camorani, Minister of Public Works

An alternative story (a dream?)

- Following the advices of some concerned geologists, Camorani did NOT authorize the Vajont dam construction
- The Vajont dam disaster did NOT happen

Longarone (BEFORE 9 October 1963*)*

Longarone (AFTER 9 October 1963*)*

An alternative story (a dream?)

- Would the strictness of Roberto Camorani be appreciated?
- Would he be rewarded for avoiding the Vajont disaster?
- Would History actually remember him?

**DISCLAIMER: Roberto Camorani is a fictious name.*
The picture of this presentation is of Friedrich August von Hayek, economist and philosopher (Nobel Price, 1974)

“everybody knows that you need more prevention than treatment,
but few reward acts of prevention”

N.N. Taleb (2007)

PREVENTION IS INVISIBLE

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SEVENTH FRAMEWORK PROGRAMME

Knowledge-based approach to develop a Culture of Risk Prevention

Instrument: EC FP7, Collaborative project

Duration: 36 months

Start Date: January 2011

Consortium: 11 partners from 6 countries

Project Coordinator: Giuliano Di Baldassarre, UNESCO-IHE Delft

UNESCO-IHE
Institute for Water Education

ECMWF

JRC
EUROPEAN COMMISSION

Univerza v Ljubljani

KING'S College LONDON

Willis

CORILA

WSL

University of BRISTOL

Autorità di Bacino

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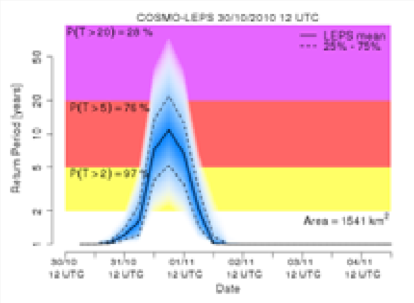
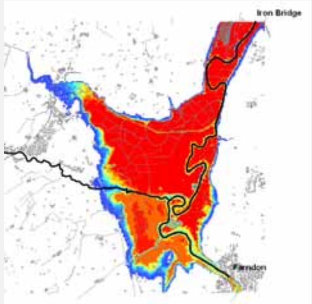
Risk prevention measures

- ☐ **<u>Risk prevention</u>** as sensible investment
- ☐ Costs of preventive measures less than the costs of post-event recovery (<u>focus on floods</u>)

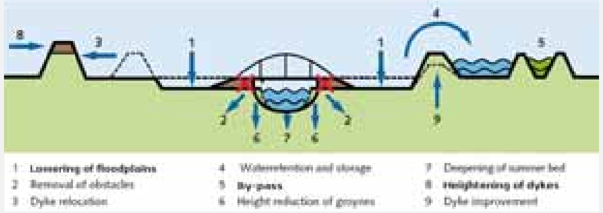
Early Warning
and Preparedness



Mapping, Planning,
Risk Transfer



Structural Measures



Risk Communication
Dialogue with Stakeholders

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SUMMER SCHOOL

FLOOD RISK REDUCTION:
PERCEPTION, COMMUNICATION, GOVERNANCE

Delft 9-12 September 2013

UNESCO-IHE Institute for Water Education, The Netherlands

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Prof. David Demeritt (King's College, London)
Dr. Matthias Buchecker (Swiss Federal Research Institute, Zurich)
Dr. Sálvano Briceño (ICSU/IRDR, retired, UN-ISDR)
Dr. Giuliano Di Baldassarre (UNESCO-IHE Institute for Water Education, Delft)

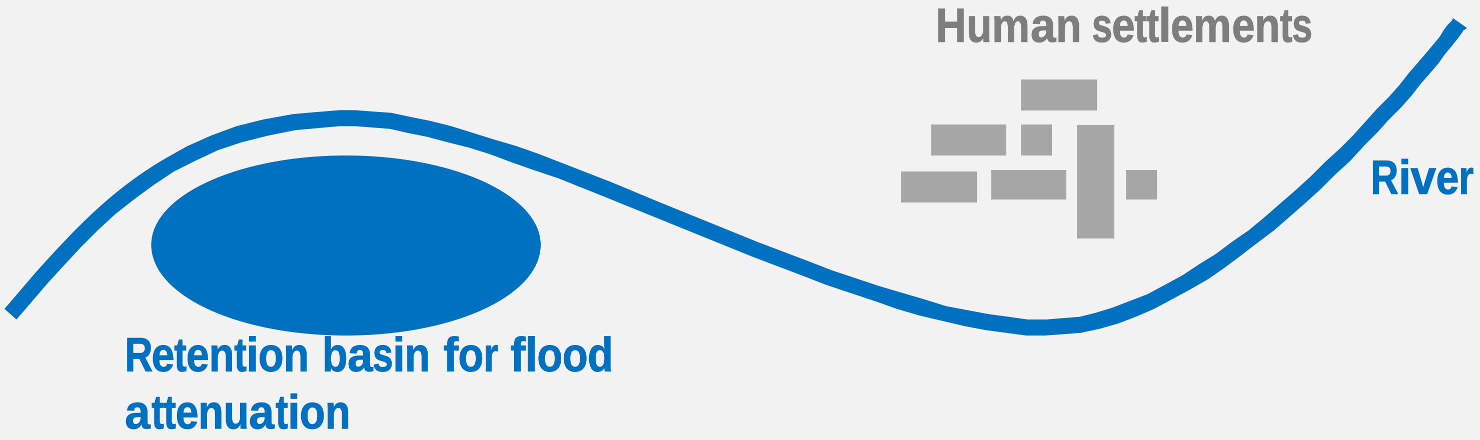
Floods and societies (hydrological sciences)

Evaluating risk prevention requires the use of models

To assess how prevention measures

reduce the frequency and severity of floods

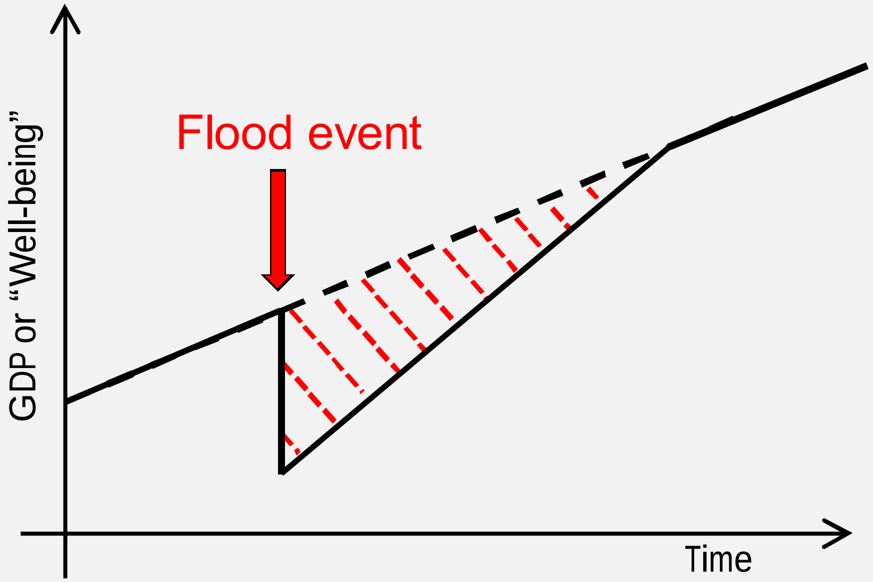
Example: retention basins to attenuate floods

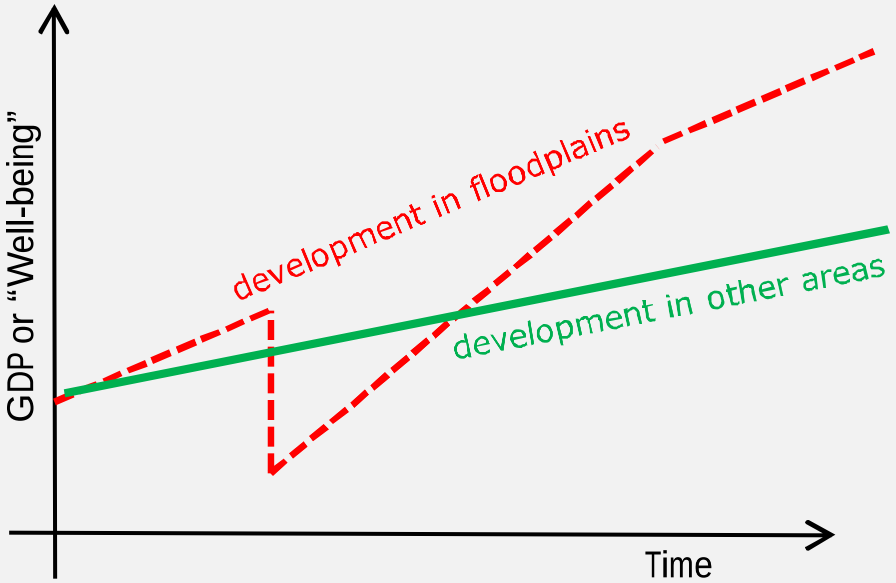


Societies and floods (social sciences)

The frequency and severity of floods (in turn) shape patterns of human settlements and land-use

Example: the occurrences of floods determine if urban development in floodplains is desirable or not





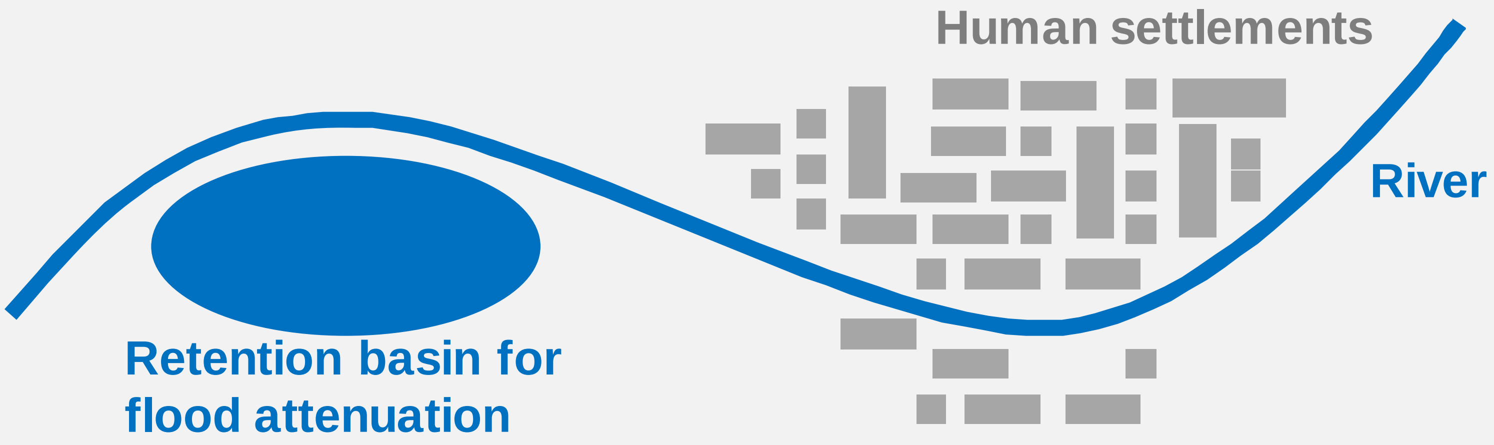
(Green et al., CONHAZ, 2011)

Floods and societies: who shapes whom?

Example: retention basins to attenuate floods

+ Reduce the frequency of flooding

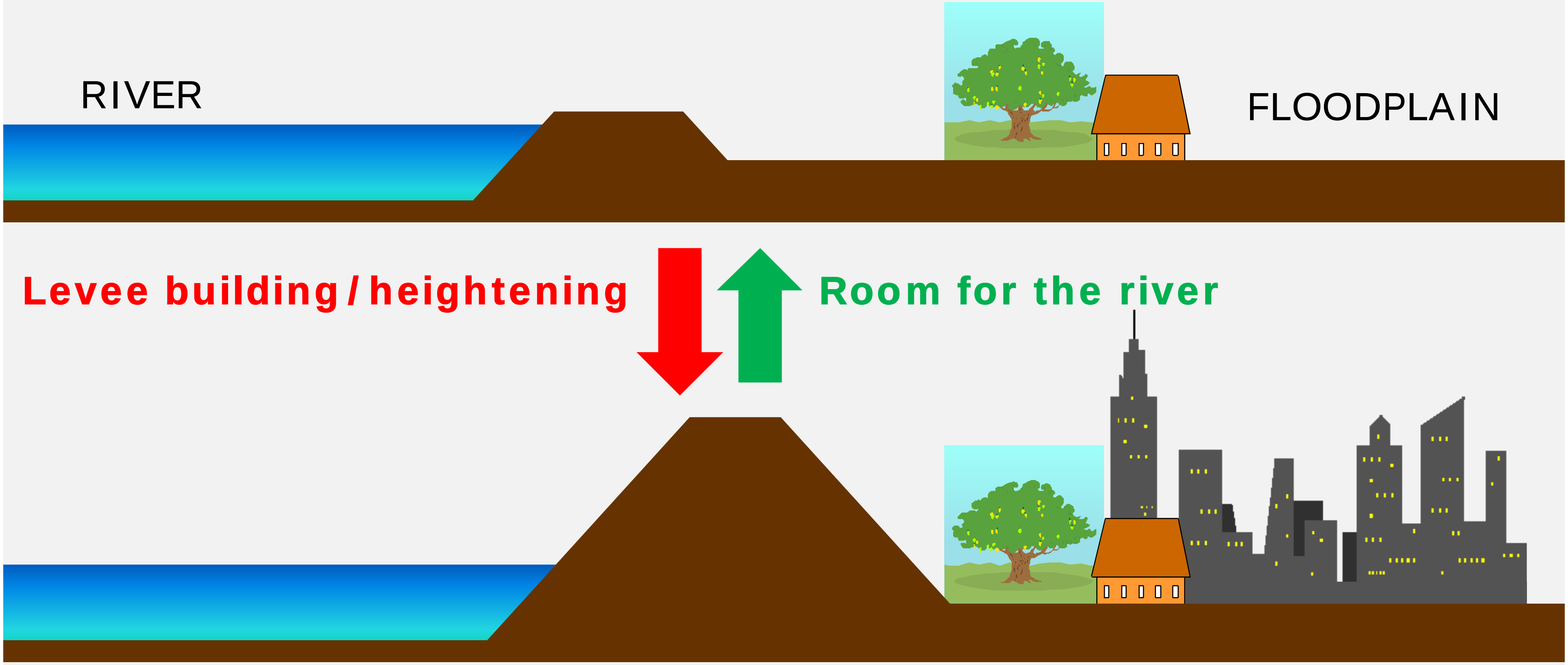
+ Increase of (formal and informal) human settlements



Flood Risk = Probability X Consequences

(Di Baldassarre et al., EGU Leonardo Conference, 2012)

Flood Risk is Dynamic!



RIVER

FLOODPLAIN

Levee building / heightening

Room for the river

Losses of ecosystem services and biodiversity

Frequent flooding TO rare (but catastrophic) flooding

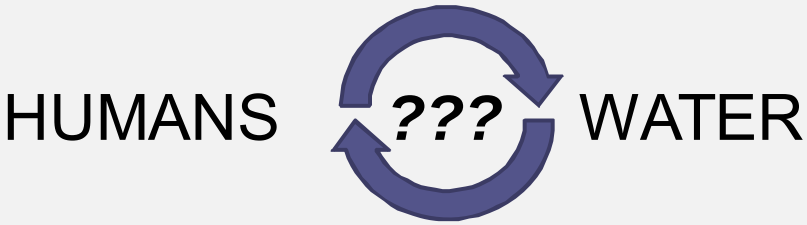
(Di Baldassarre et al., Hydrology and Earth System Science Discussion, 2013)

Floodplains as human-water systems

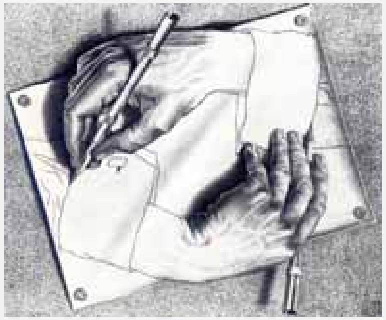
Need to understand how societies influence the frequency of floods, while (at the same time) the frequency of floods shapes societies, which (in turn) alter future floodplain dynamics…

Human and water systems are deeply intertwined

Interactions and feedback loops are poorly understood



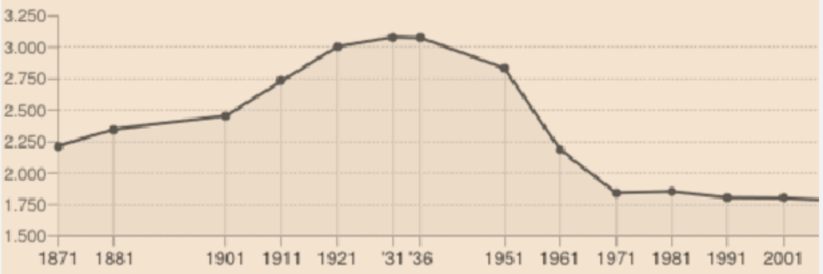
HUMANS ***???*** WATER

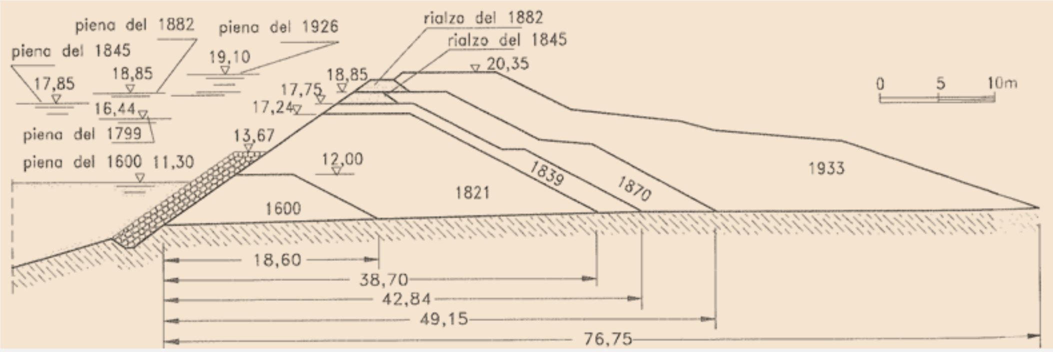


“Drawing Hands” by Escher (1948)

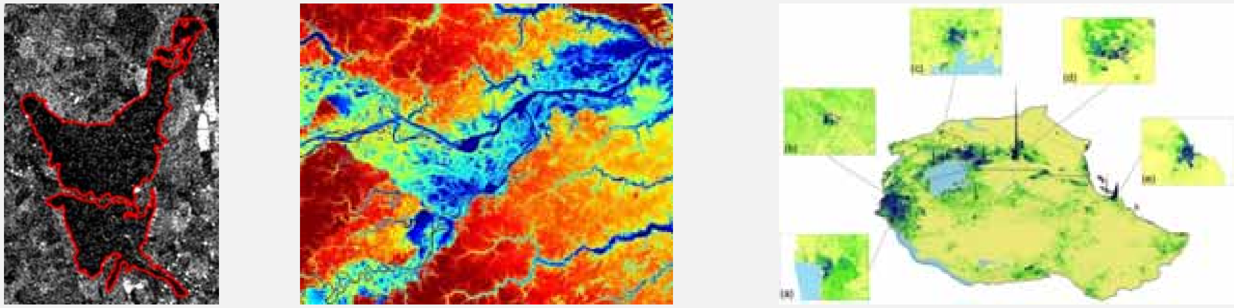
Socio-hydrology of floodplains

i. Historical analysis of hydrological and demographic changes in a variety of case studies





ii. Comparative analysis of floodplain dynamics, benefiting from the current proliferation of remote sensing data



iii. Conceptualization of human-flood interactions and feedbacks to explore the dynamics of floodplain systems

Socio-hydrology of floodplains

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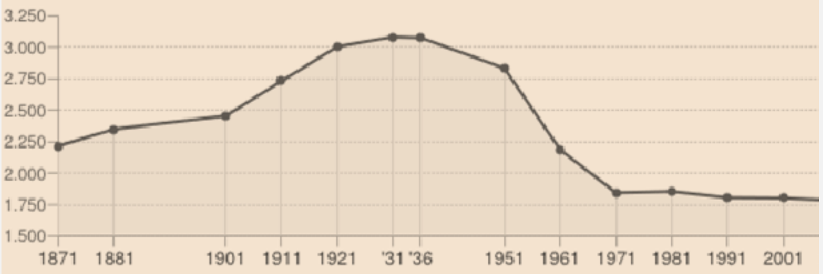

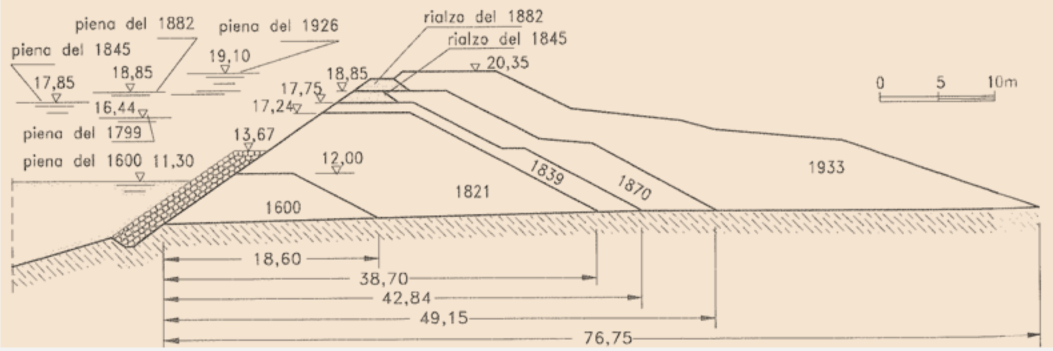

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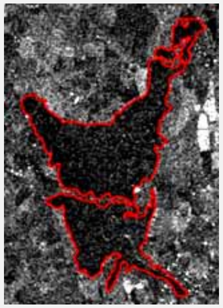
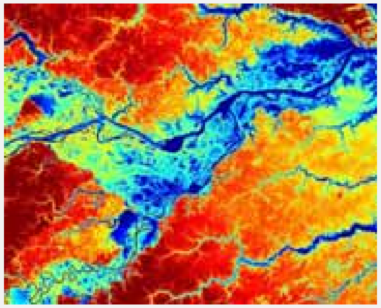
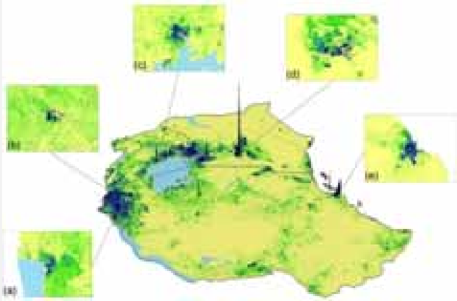


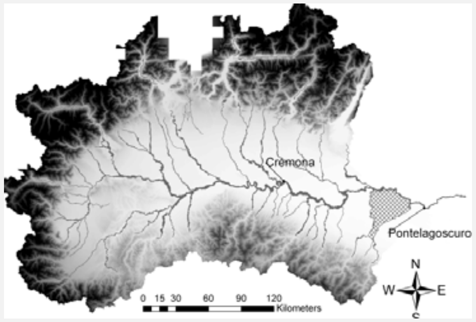




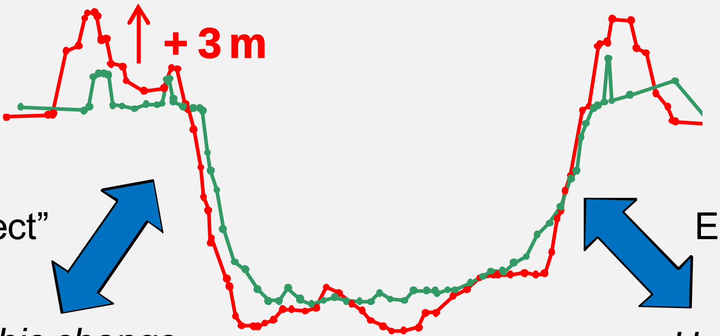
iii. Conceptualization of human-flood interactions and feedbacks to explore the dynamics of floodplain systems

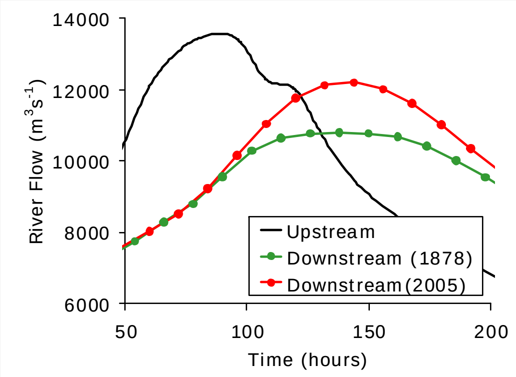
Floodplains as human-water systems

River Po (Italy): levee building and heightening



Human activities



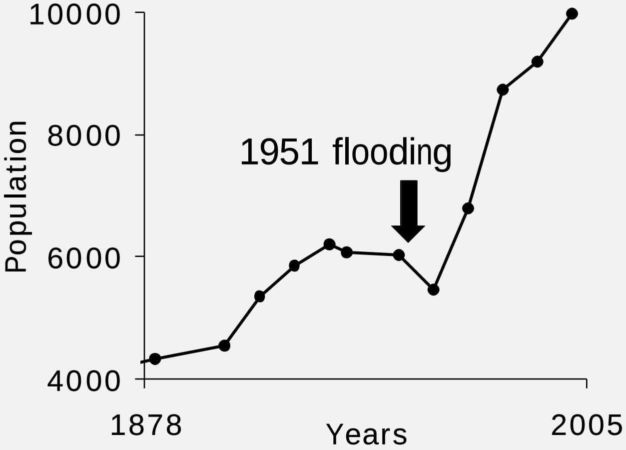


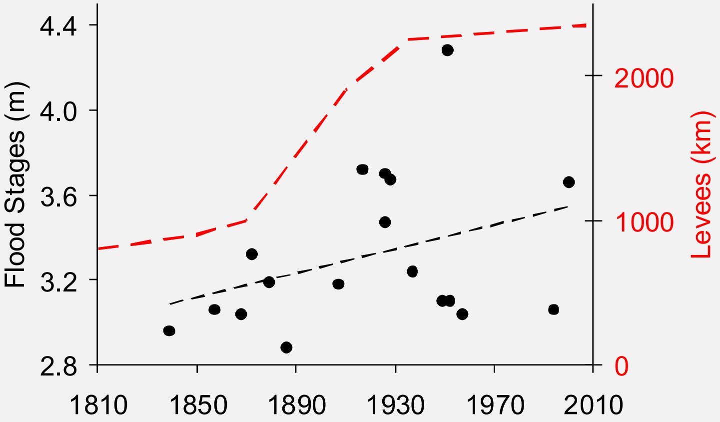
"Levee effect"

Exacerbation of high water levels

Demographic change

Hydrological change

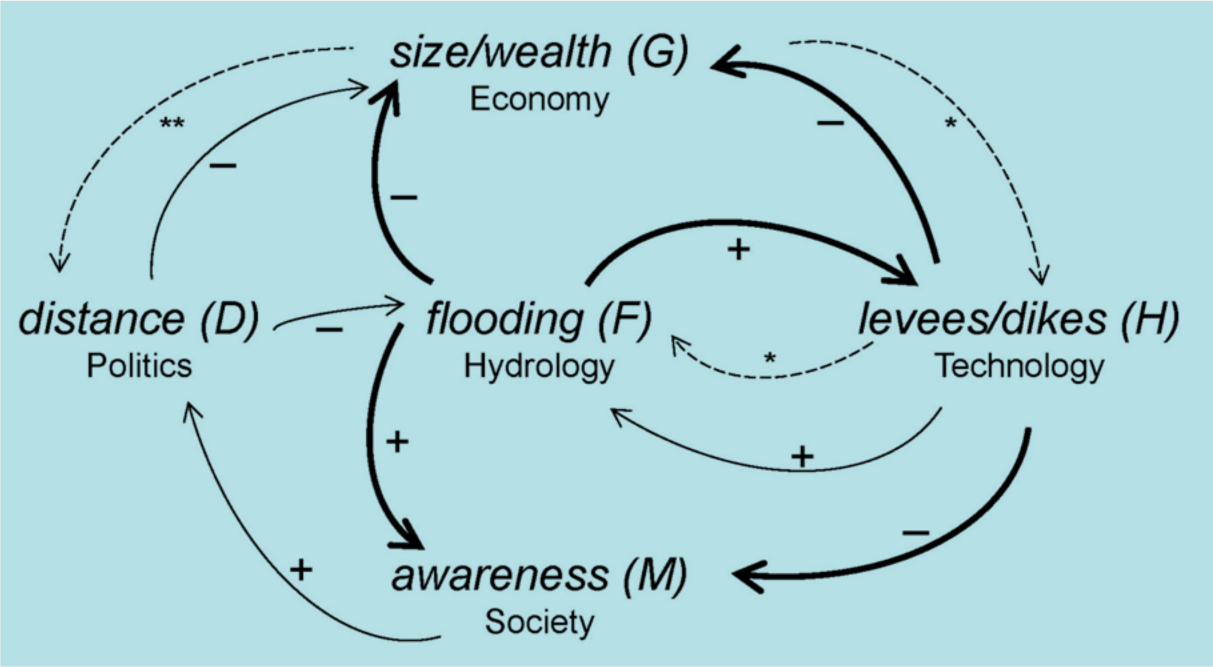




(Di Baldassarre et al., Hydrological Sciences Journal, 2009)

Conceptualizing human-flood interactions

Mathematical dynamic modelling of floodplain systems



Social and hydrological components are all interlinked,
and **gradually co-evolve**,
while being **abruptly altered** by the occurrence of **flooding events**

(Di Baldassarre et al., Hydrology and Earth System Science Discussion, 2013)

Conceptualization: narrative

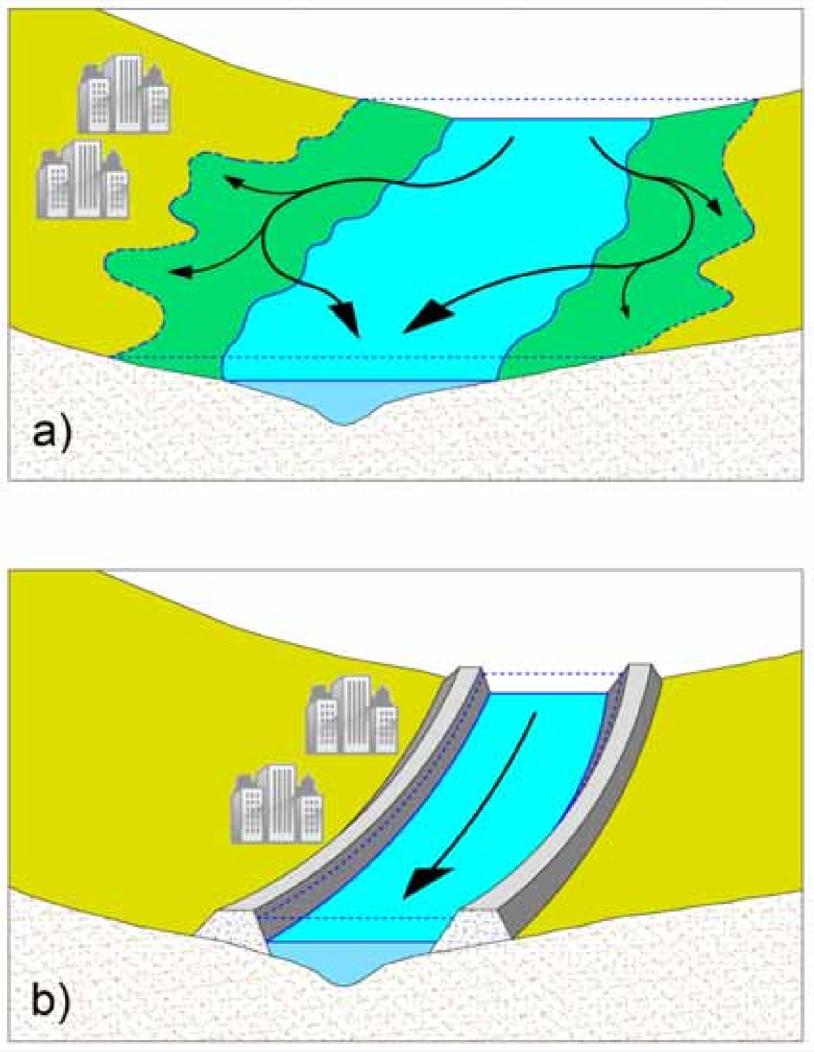
Community that starts settling and developing in a floodplain

Human settlement develops close to river and gain the associated economic benefits (e.g. trading)

Abrupt occurrence of flooding causes economic damages

After flooding, community is shocked and builds risk awareness

People move away from
the river (a) or raise levees (b)

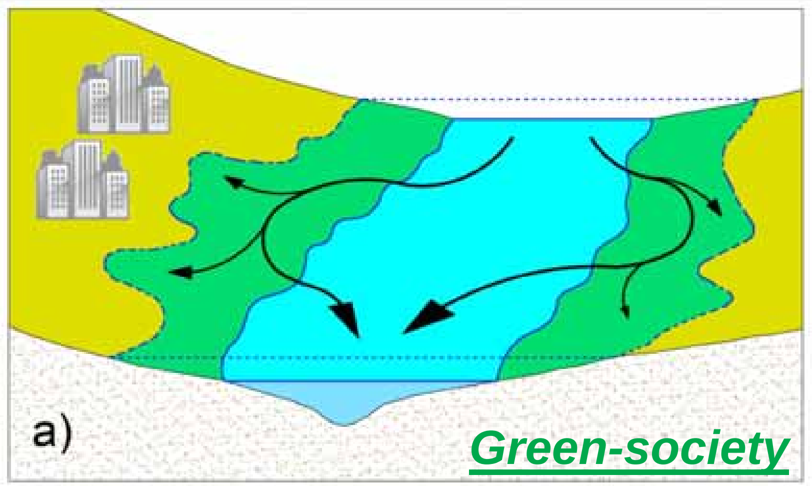


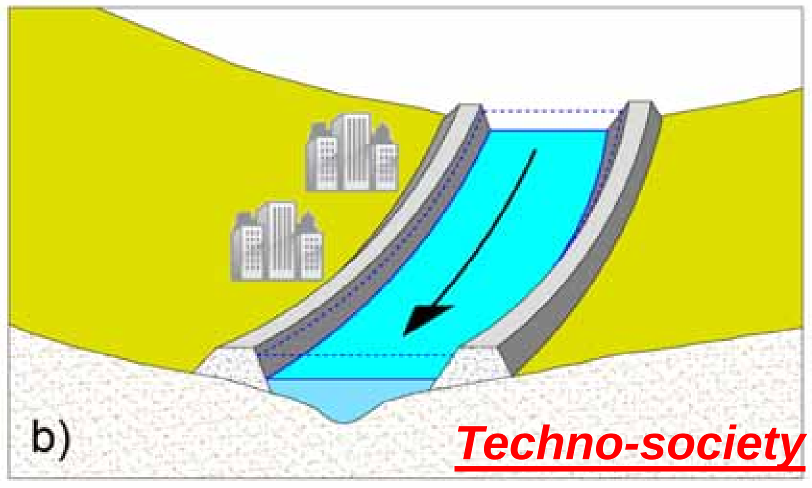
Conceptualization: narrative

If the human settlement moves away (a), part of the benefits are lost

Building levees (b) also has a cost, and it feeds back on the hydrology: levees exacerbate high water levels

Risk awareness decays with time
Tendency to get close to the river

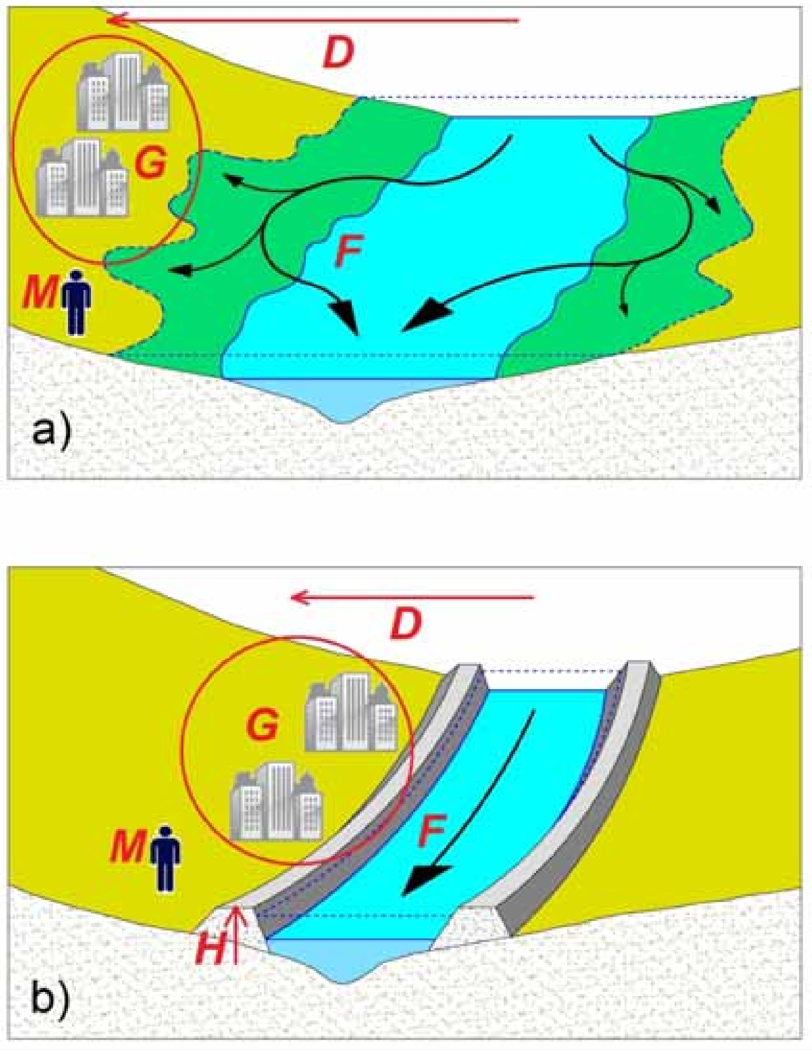




Green-society *VS* ***Techno-society***

Conceptualization: mathematics

F = intensity of flooding (relative damage)
H = flood protection level (e.g. levees)
D = distance from the river
G = wealth/size of the human settlement
M = risk awareness



Conceptualization: mathematics

Hydrology equation (flooding as single events):

High water level

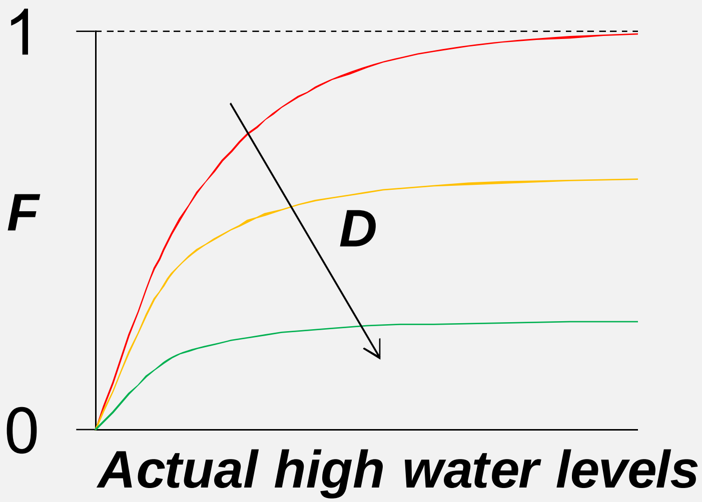
Exacerbation

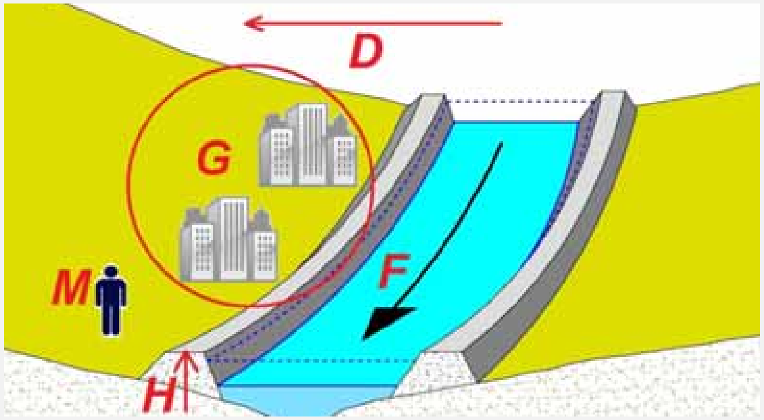
$$F = 1 - \exp\left(-\frac{W + \xi_H H}{\alpha_H D}\right) \qquad \text{if } \boxed{W + \xi_H H} > H$$

Parameter related to topography (slope)

Actual water level

$$F = 0 \qquad otherwise$$





F = intensity of flooding (relative damage)

W = high water level

H = flood protection level (e.g. levees)

D = distance from the river

G = wealth/size of the human settlement

M = risk awareness

Conceptualization: mathematics

Raising dikes/levees (immediately after flooding events)

Actual water level

Damage

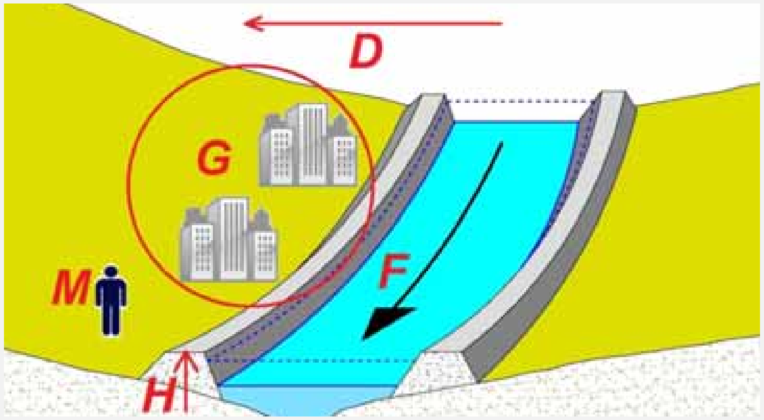
Cost of flood protection

Wealth after flooding

$$R = \varepsilon_T\left(W + \xi_H H_- - H_-\right) \quad if \left(FG_- > \gamma_E R\sqrt{G_-}\right) \quad and \quad \left(G_- - FG_- > \gamma_E R\sqrt{G_-}\right)$$

Safety factor

$$R = 0 \qquad otherwise$$



F = intensity of flooding (relative damage)

W = high water level

H = flood protection level (e.g. levees)

D = distance from the river

G = wealth/size of the human settlement

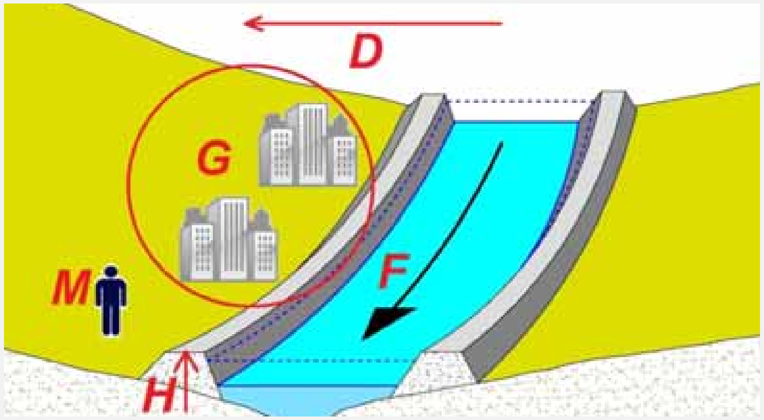
M = risk awareness

Conceptualization: mathematics

Psychological shock, immediately after flooding events (building risk awareness)

Proportion of shock after flooding if levees are raised (remedy)

$$S = \alpha_S F \quad if\left(R > 0\right)$$
$$S = F \qquad otherwise$$



F = intensity of flooding (relative damage)
W = high water level
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Conceptualization: mathematics

Non periodic Dirac comb

Maximum relative growth rate

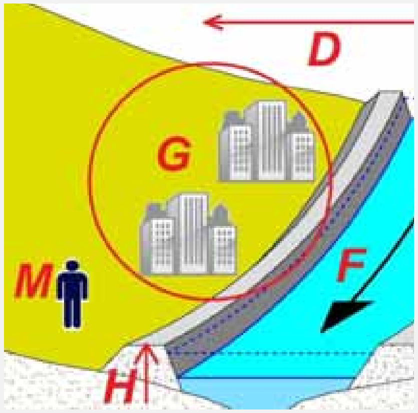
Cost of flood protection

Damage

$$\frac{dG}{dt} = \rho_E\left(1-\frac{D}{\lambda_E}\right)G - \Delta\big(\psi(t)\big)\cdot\left(FG+\gamma_E R\sqrt{G}\right)$$

Distance of no growth

Economy



$$\frac{dD}{dt} = \left(M-\frac{D}{\lambda_P}\right)\frac{\varphi_P}{\sqrt{G}}$$

Resettling capability rate

Distance perceived as completely safe

Politics

$$\frac{dH}{dt} = \Delta\big(\psi(t)\big)\cdot R - \kappa_T H$$

Decay rate of flood protection structures

Technology

$$\frac{dM}{dt} = \Delta\big(\psi(t)\big)\cdot S - \mu_S M$$

Decay rate of risk awareness

Society

Conceptualization: mathematics

$$\begin{cases} \dfrac{dG}{dt} = \rho_E \left(1 - \dfrac{D}{\lambda_E}\right) G - \Delta(\psi(t)) \cdot \left(FG + \gamma_E R\sqrt{G}\right) \\ \dfrac{dD}{dt} = \left(M - \dfrac{D}{\lambda_P}\right) \dfrac{\varphi_P}{\sqrt{G}} \\ \dfrac{dH}{dt} = \Delta(\psi(t)) R - \kappa_T H \\ \dfrac{dM}{dt} = \Delta(\psi(t)) S - \mu_S M \end{cases}$$

Economy

Politics

Technology

Society

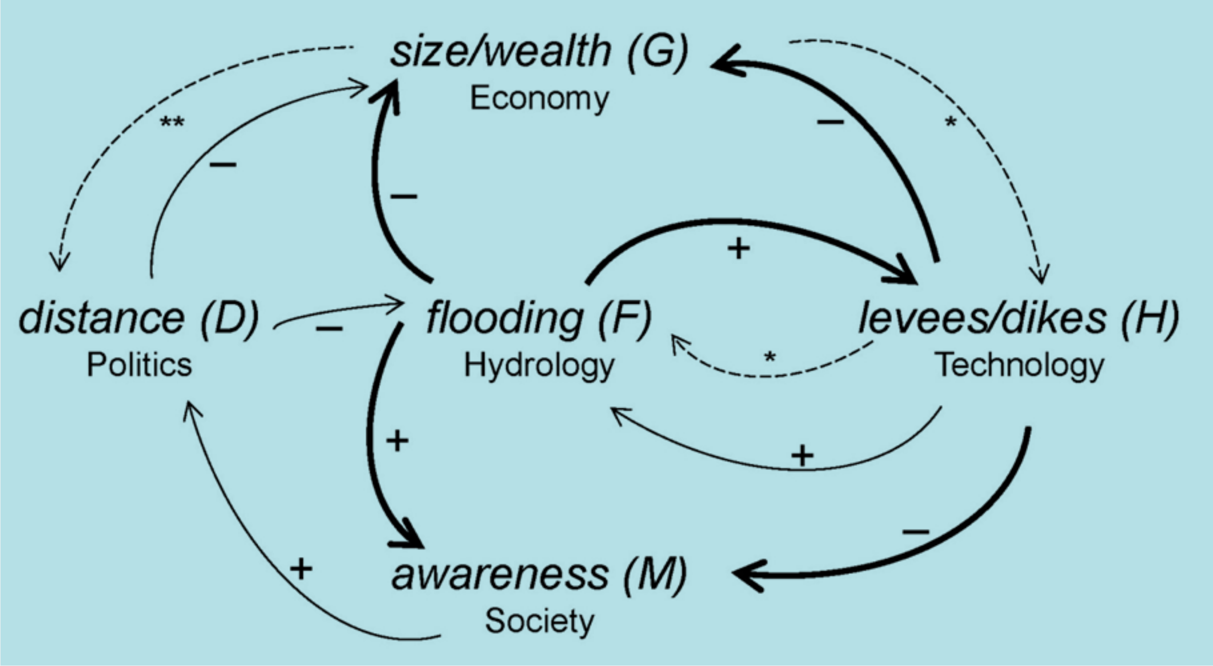
Two-way coupling of human and water systems

$$F = 1 - \exp\left(-\frac{W + \xi_H H}{\alpha_H D}\right) \quad if\ W + \xi_H H > H$$

Hydrology

Conceptualizing human-flood interactions

Mathematical dynamic modelling of floodplain systems

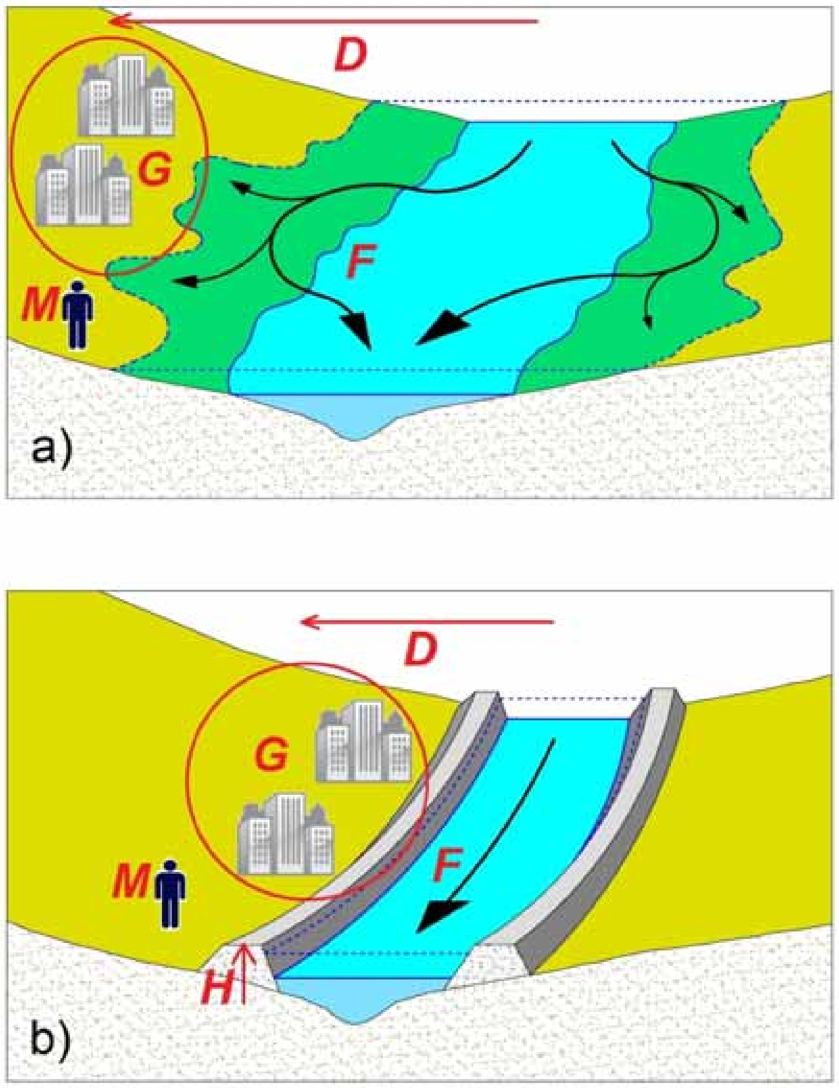


Social and hydrological components are all interlinked,
and **gradually co-evolve**,
while being **abruptly altered** by the occurrence of **flooding events**

Example applications

WetTown settles in the floodplain of the WildWaters River and starts trading

At time $t = 0$:
Small village of 10,000m^2
At 2,000m from the river
People do not have flooding experience
No flood protection measures



Example applications

Assumptions:

The vicinity to the river allows a maximum growth-rate of 2% (ρ_E)

Benefits vanish settling at 5,000m (λ_E)

High water levels may potentially inundate WetTown ($\alpha_H = 0.01$)

Levees determine a 50% exacerbation of the high water levels ($\zeta_H = 0.5$)

Shock is halved if levees are raised ($\alpha_S = 0.5$)

Risk awareness decays by 50% in 15 years ($\mu_S = 0.05$ yr^{-1})

The distance perceived completely safe is 12,000m (λ_P)

The ability to resettle is proportional to $\phi_P = 100^2$ m^2 yr^{-1}

Example applications

Simulations:

3 different unit costs of building/raising levees:

- low-cost **($g_E = 0.5$)**

- moderate-cost **($g_E = 50$)**

- high-cost **($g_E = 5000$)**

Decay of protection levels about 50% in 200 years ($k_T = 3\times10^{-3}$ yr^{-1})

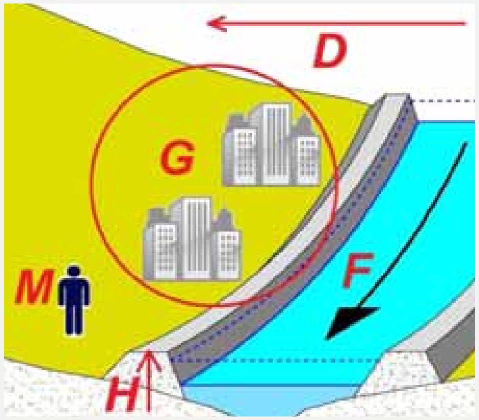
Results 1/2

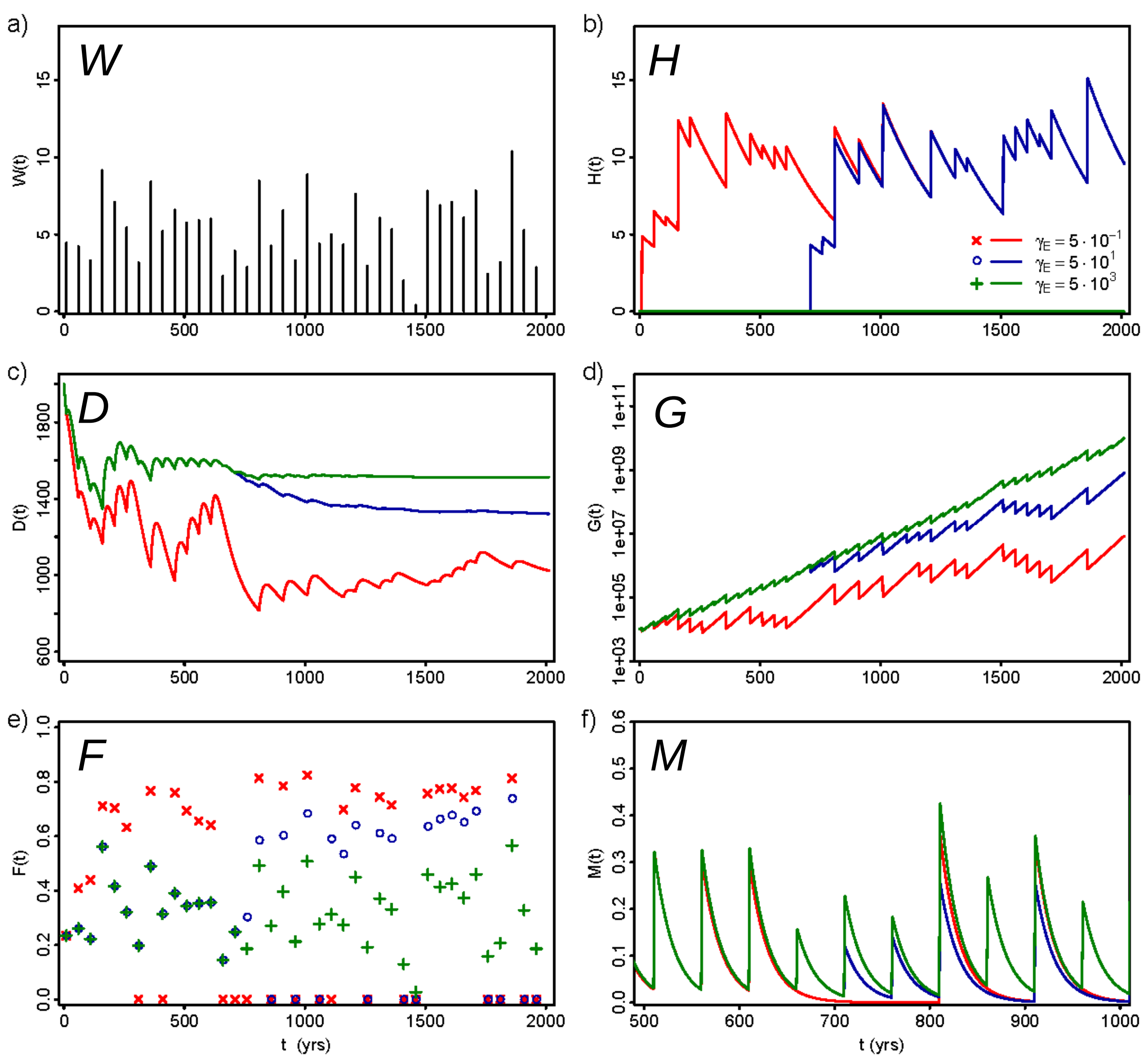
Decay of protection levels about 50% in 200 years

- low-cost

- moderate-cost

- high-cost





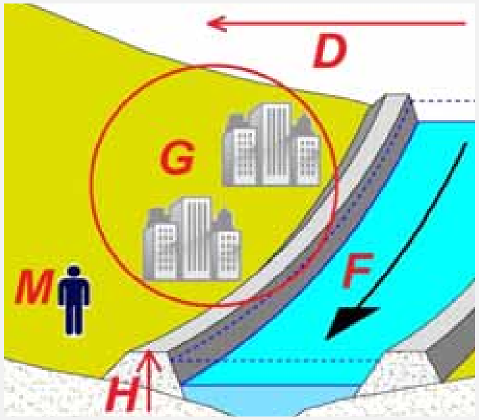
Results 2/2

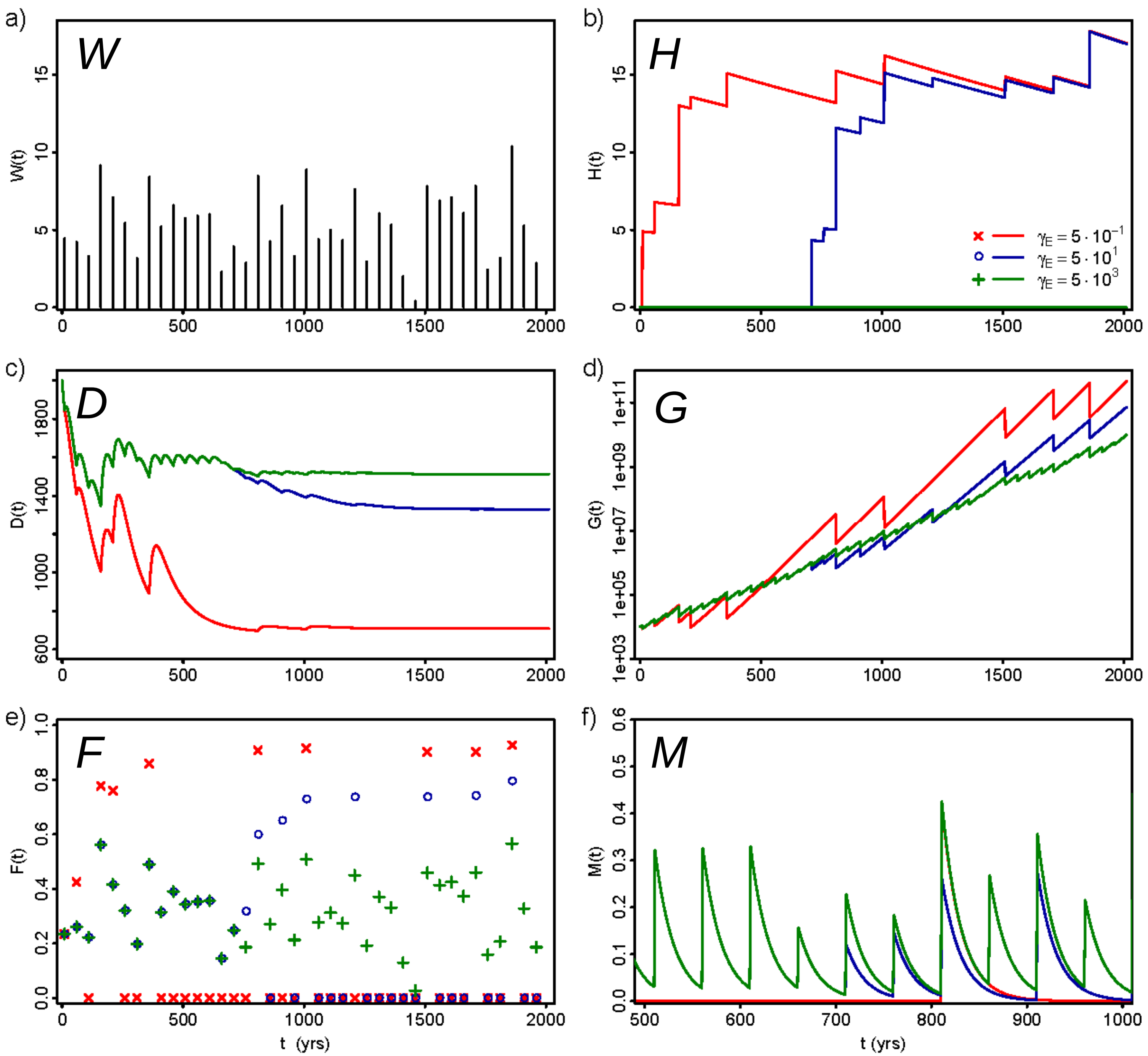
Decay of protection levels about 5% in 200 years

- low-cost

- moderate-cost

- high-cost





Conclusions

Conceptualization of flood-people interactions

Focus on the interactions and feedback mechanisms between hydrological and social processes

Able to simulate typical long-term dynamics, such as the shift from frequent flood events to rare, but catastrophic, flood disasters

Complexity of hydrological, economical, political, technological, and social processes was simplified

Not a predictive tool for a specific location, but rather
educated hypothesis of how floodplain systems work
unraveling of feedbacks between human and water systems

Perspectives

Test assumptions by exploring the socio-hydrology of floodplains:

- Historical analysis (River Po, Netherlands, Bangladesh, etc…)
- Comparative analysis (across scales, human impacts, cultures)

Final goal:
Developing theories to explain the behavior of floodplain systems