Climate change impacts on freshwater and urban environments

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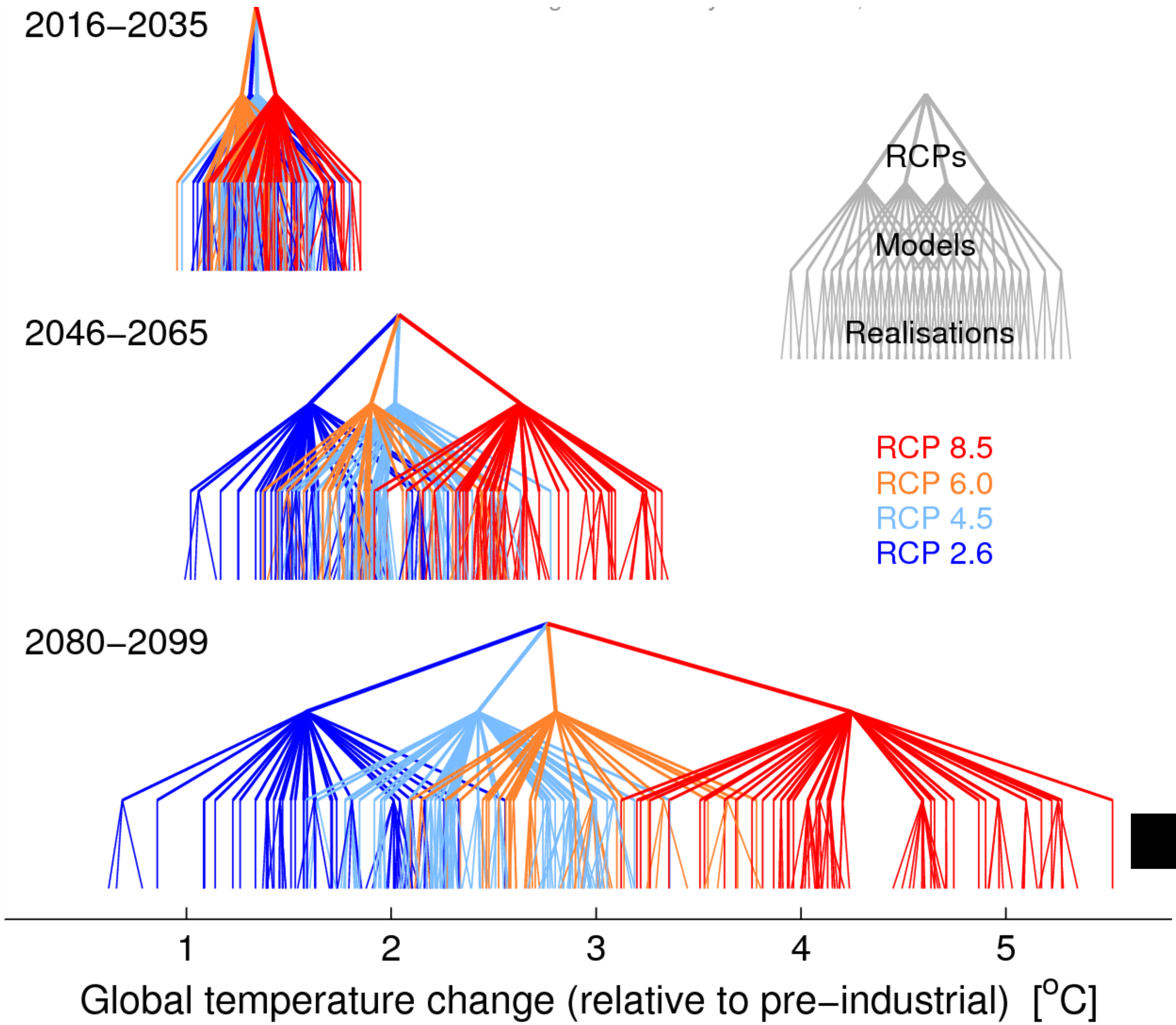
Conventional scenario-led frameworks…



An actual 'cascade of uncertainty' in global mean surface temperature from the CMIP5 ensemble for selected periods.

Source: Ed Hawkins
http://www.climate-lab-book.ac.uk/2014/cascade-of-uncertainty/#more-1988

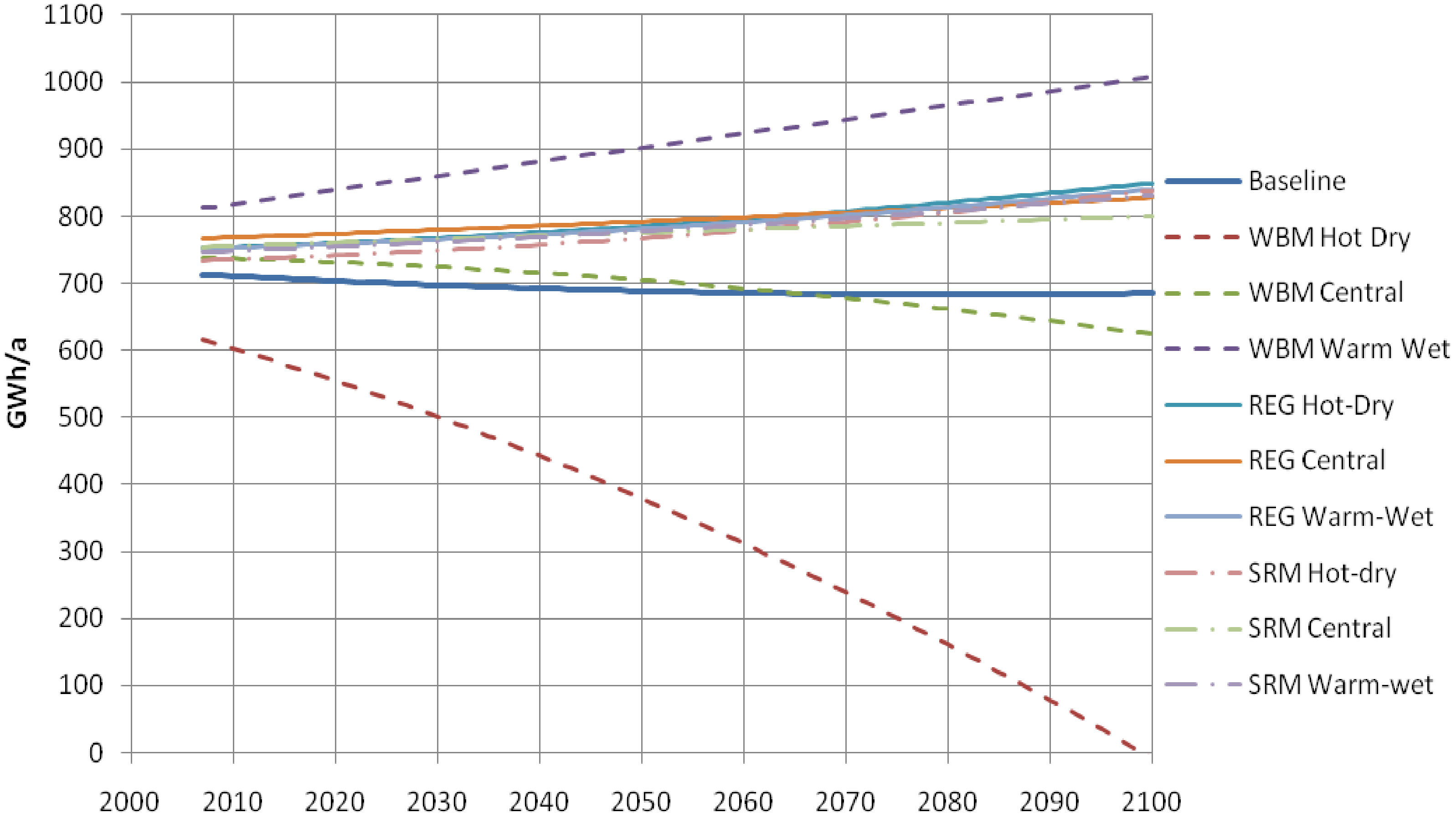
Impact model uncertainty and beyond

…typically get mired in uncertainty and default to ‘low-regret’ recommendations

Climate scenario method	Adaptation options analysis				
	Not done	Low-regret	Adaptively managed	Precautionary principle	Cost-benefit
Qualitative	1	2	0	0	0
Sensitivity test	2	0	½	1	2½
Scenario-led	5	10½	½	1	2

Source: Wilby, R.L. 2012. *Utility of climate model scenarios for water policy, investment and operational decisions*. Report on behalf of the World Bank Independent Evaluation Group, Washington, 49pp.

Is there another way?



Model simulations of future annual energy production at Kairakkum, Tajikistan. Source: EBRD (2011)

Case study 1: Hot spot analysis

Mapping climate change impacts on smallholder agriculture in Yemen using GIS modelling approaches

Draft Final Technical Report

29 January 2013

Wadi Hadramaut. Photo: Arthur Bull (1930)

Robert Wilby and Dapeng Yu
Climate and Hydrological Science Advisors

On behalf of
International Fund for Agricultural Development (IFAD)

Republic of Yemen Rural Growth Programme: Pilot approach to site selection (in Dhamar)

Technical Report

5 July 2013

An example village unit with potential for stone terrace rehabilitation

Robert Wilby and Dapeng Yu
Climate and Hydrological Science Advisors

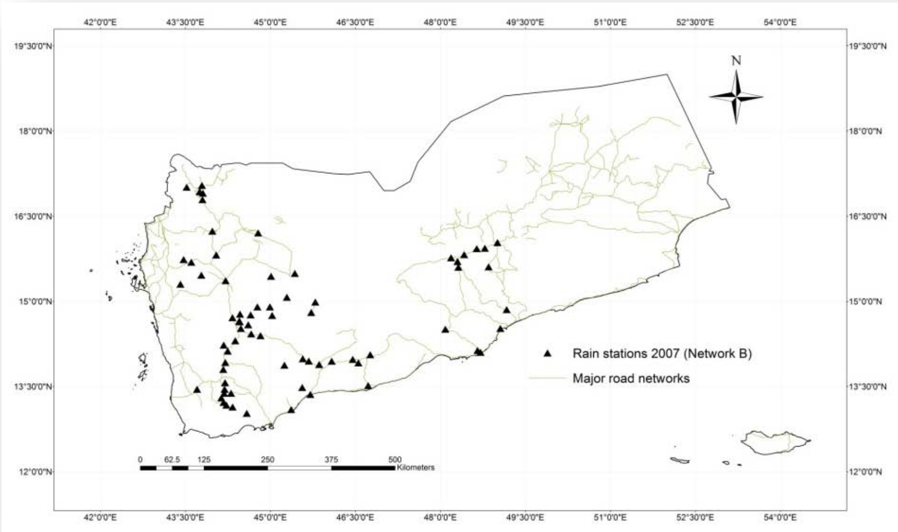
On behalf of
International Fund for Agricultural Development (IFAD)

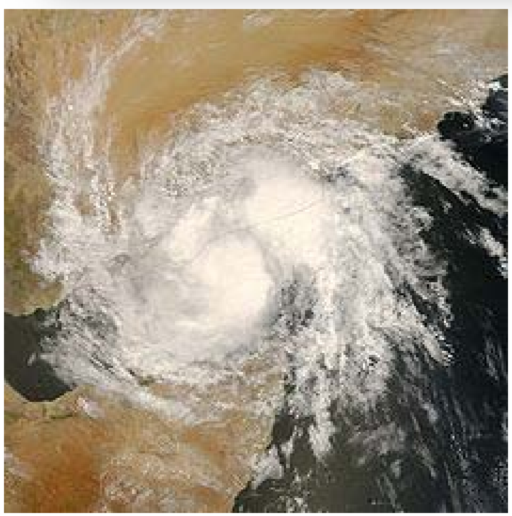
Some vital statistics of Yemen*

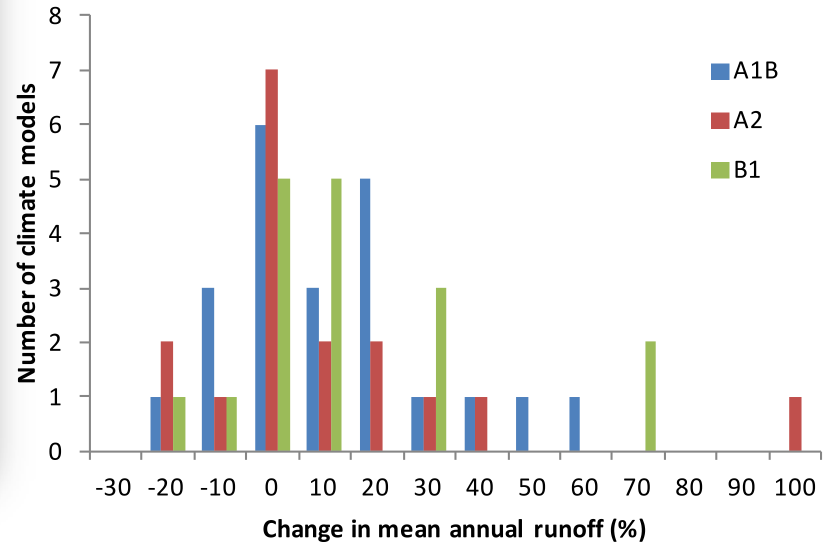
Indicators	**Score**
Population (millions)	24.3
Growth rate of population (%/year) 2005-2010	2.9
Gross domestic product ($US per capita) in 2009	1060
Life expectancy at birth (years)	60
Underweight children under 5 years (%)	46
Renewable freshwater resources (m^3/year/per capita)	169
Rural population with access to sanitation (%)	30
Human Development Index (rank)	140/182
Gender Empowerment Index (rank)	109/109

*Sources: United Nations/ World Bank

Sparse data, complex climate, uncertain outlook



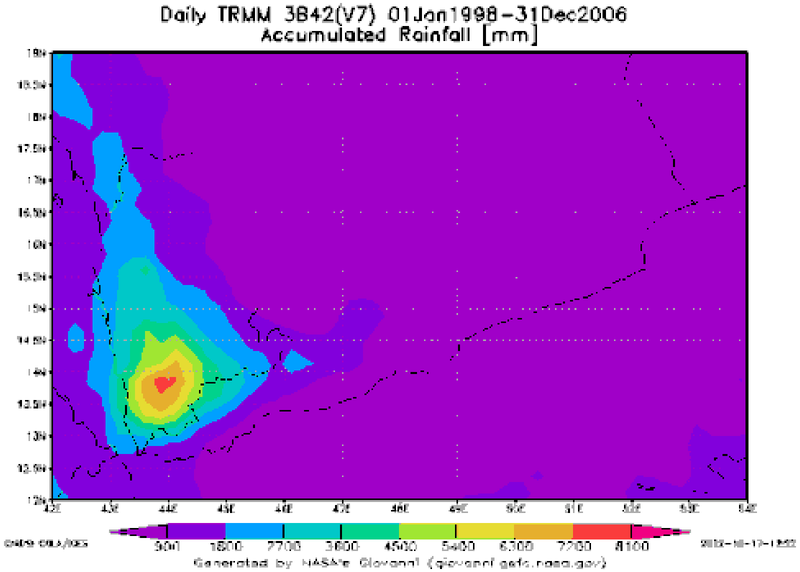


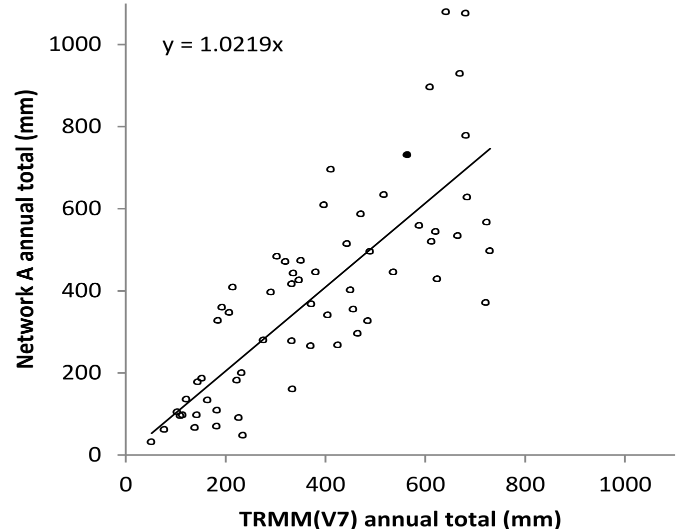


Example output from the World Bank Group Climate Change Knowledge Portal for river basin 5438 in Yemen. The histogram shows the distribution of projected changes in mean annual runoff under three emissions scenarios (A1B, A2 and B1) for 2050-2059. Source: Wilby (2012)

Solution: Remotely sensed variables

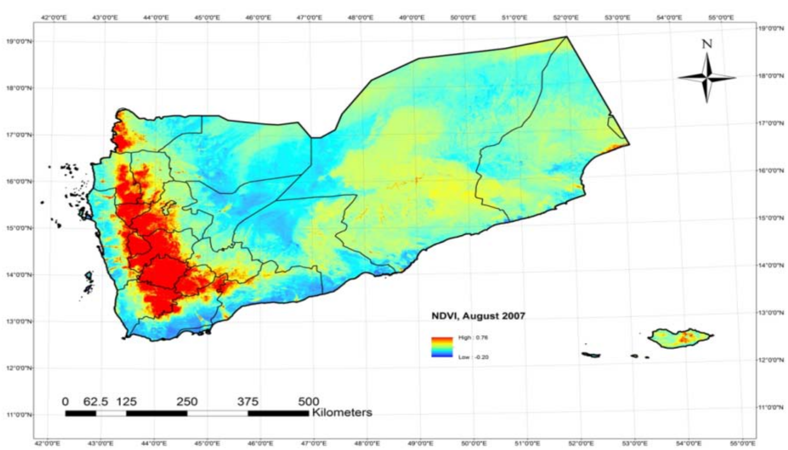
TRMM(V7)

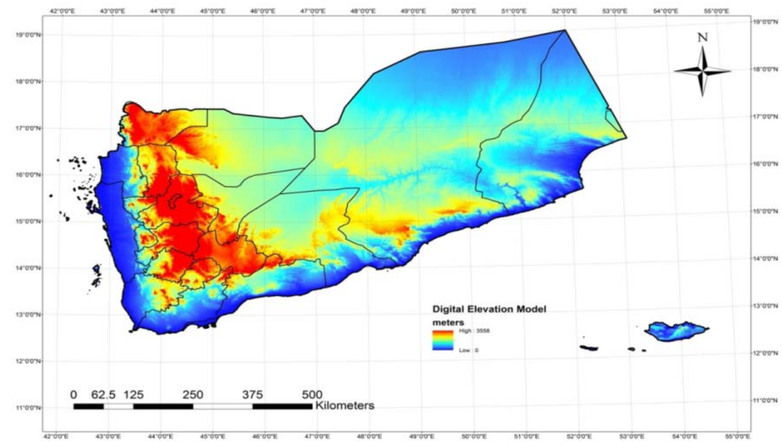




TRMM(V7) v OBS

NDVI

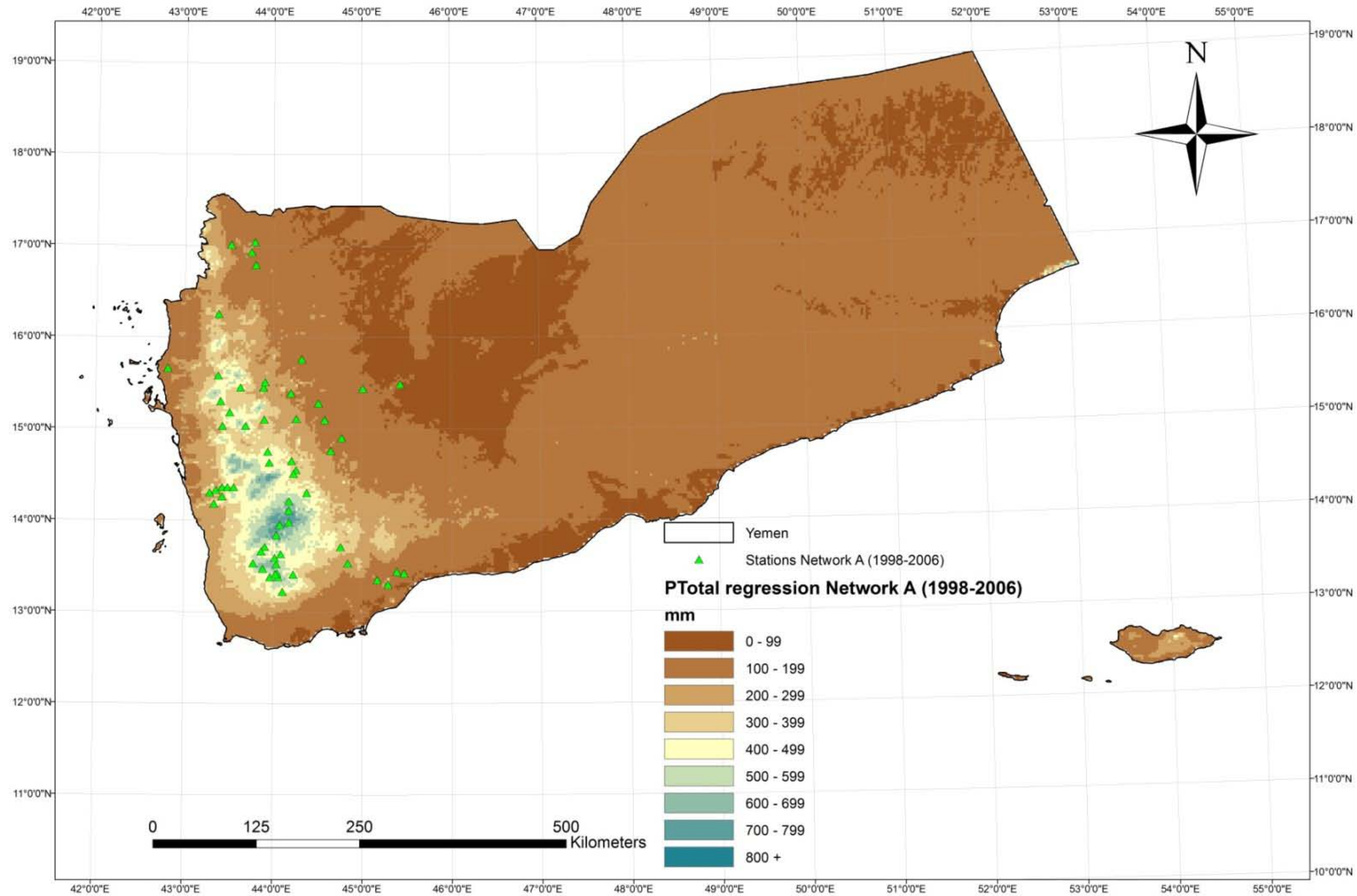




DEM

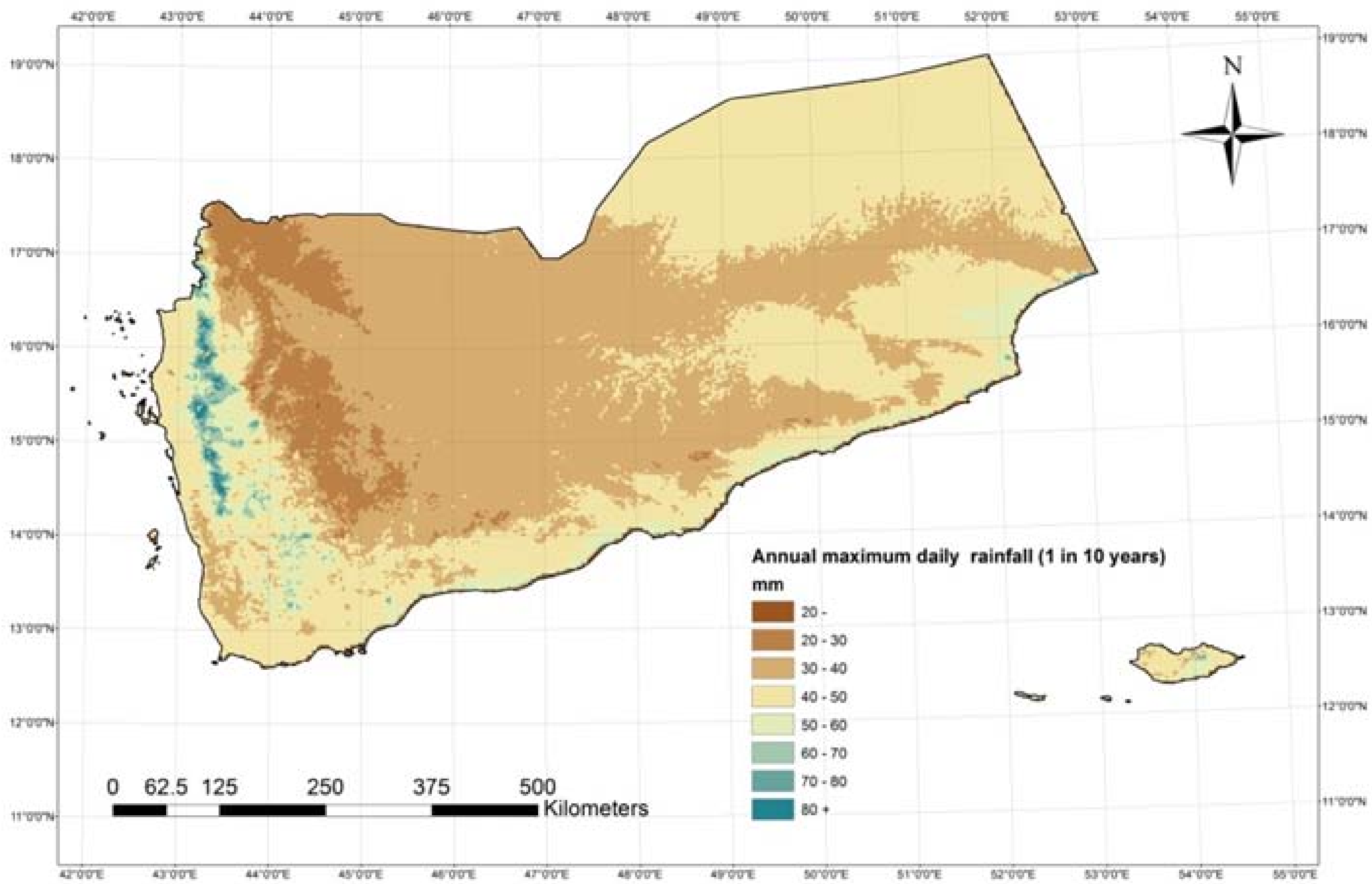
Loughborough University

Blending satellite and surface observations



Source: Wilby and Yu (2013) *HESS*, **17**, 3937-3955

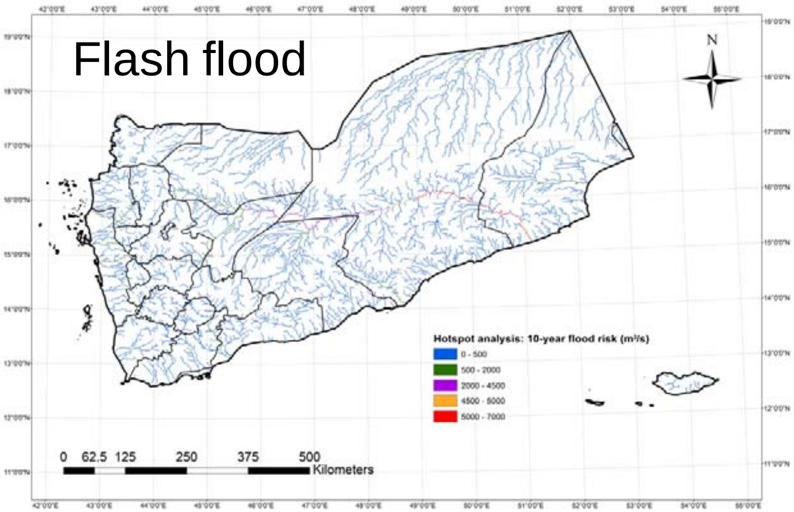
Corroboration (qualitative*)

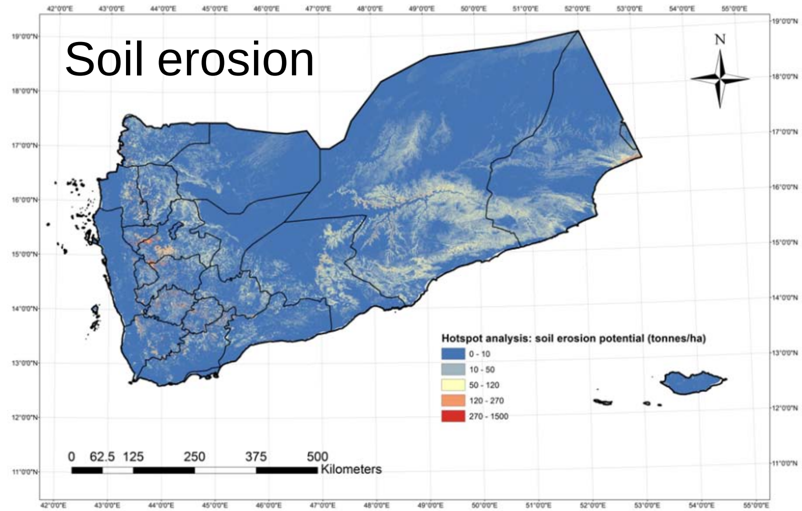


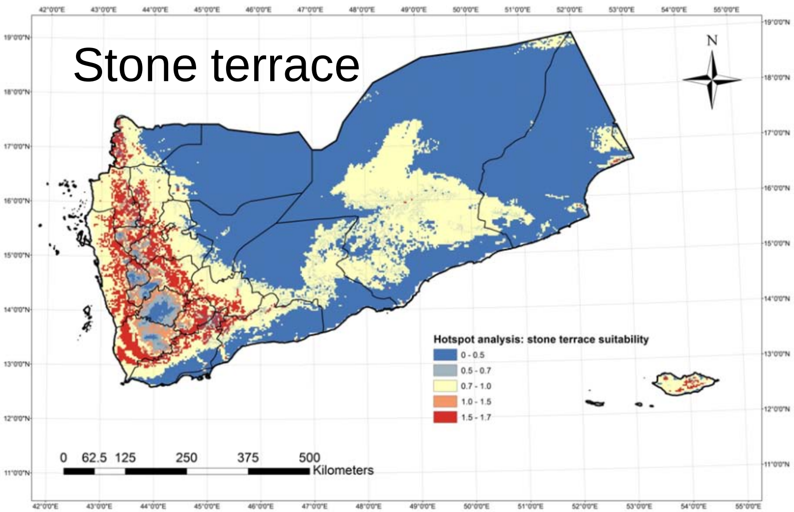
Estimated 10-year return period daily rainfall totals based on topographic and remotely sensed data for data sparse Yemen.

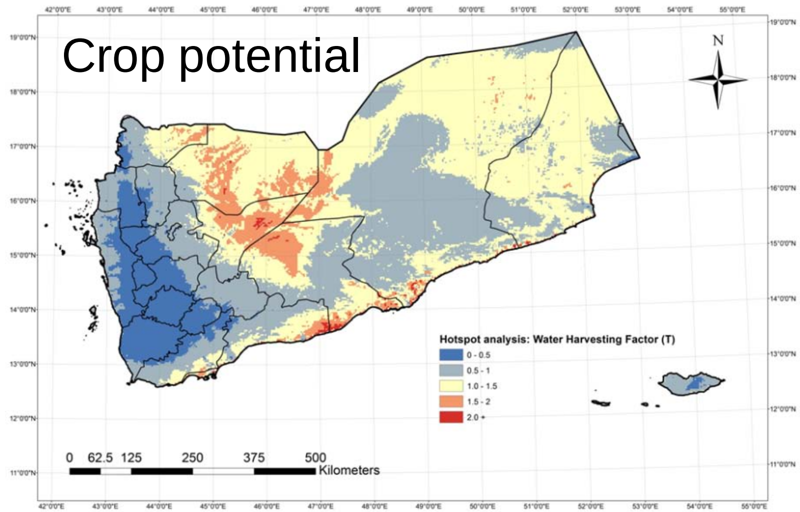
* Compared with Dartmouth Flood Observatory

"Hot spot" analysis (T: 0 to 4°C, P: -40 to +20%)





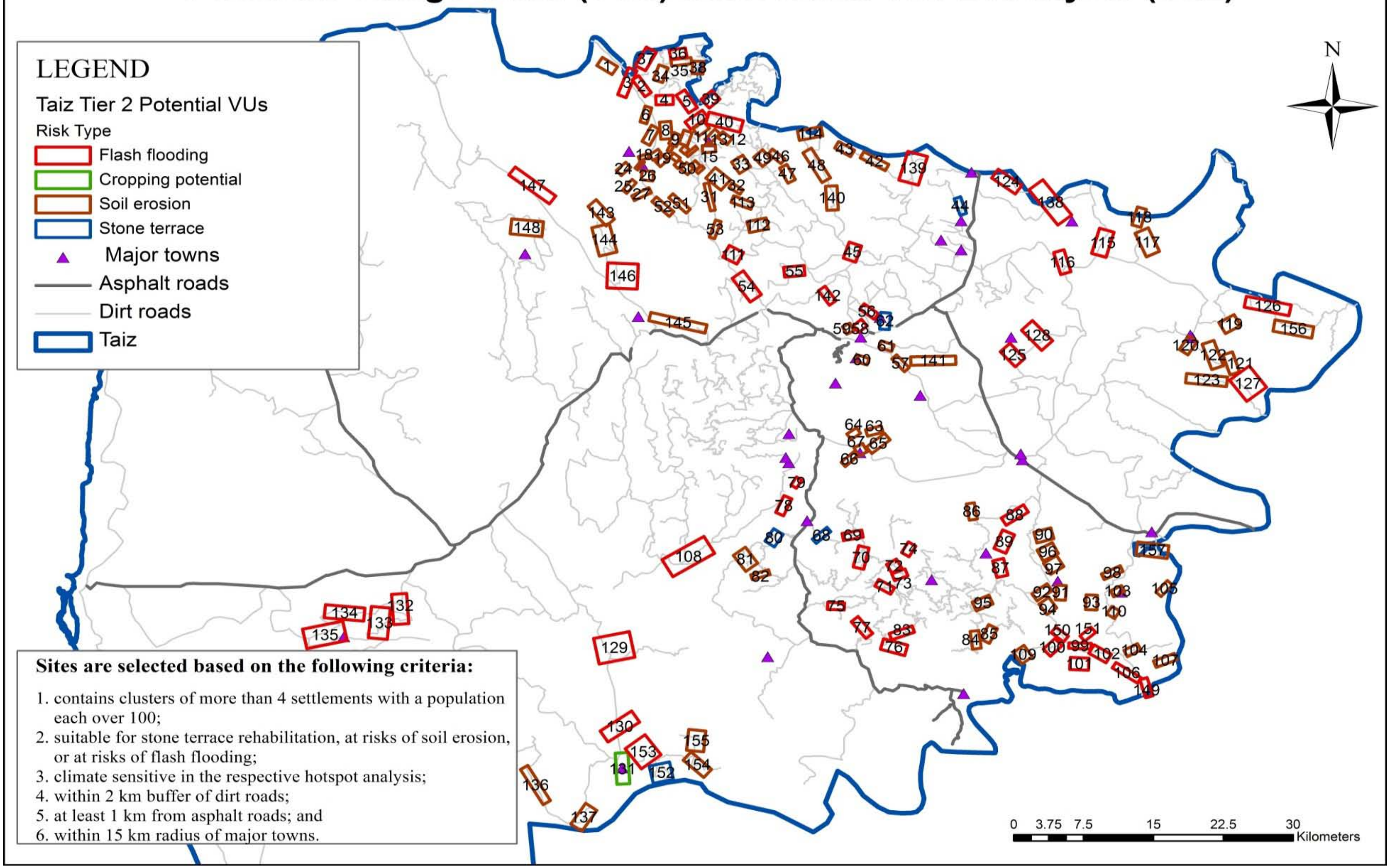




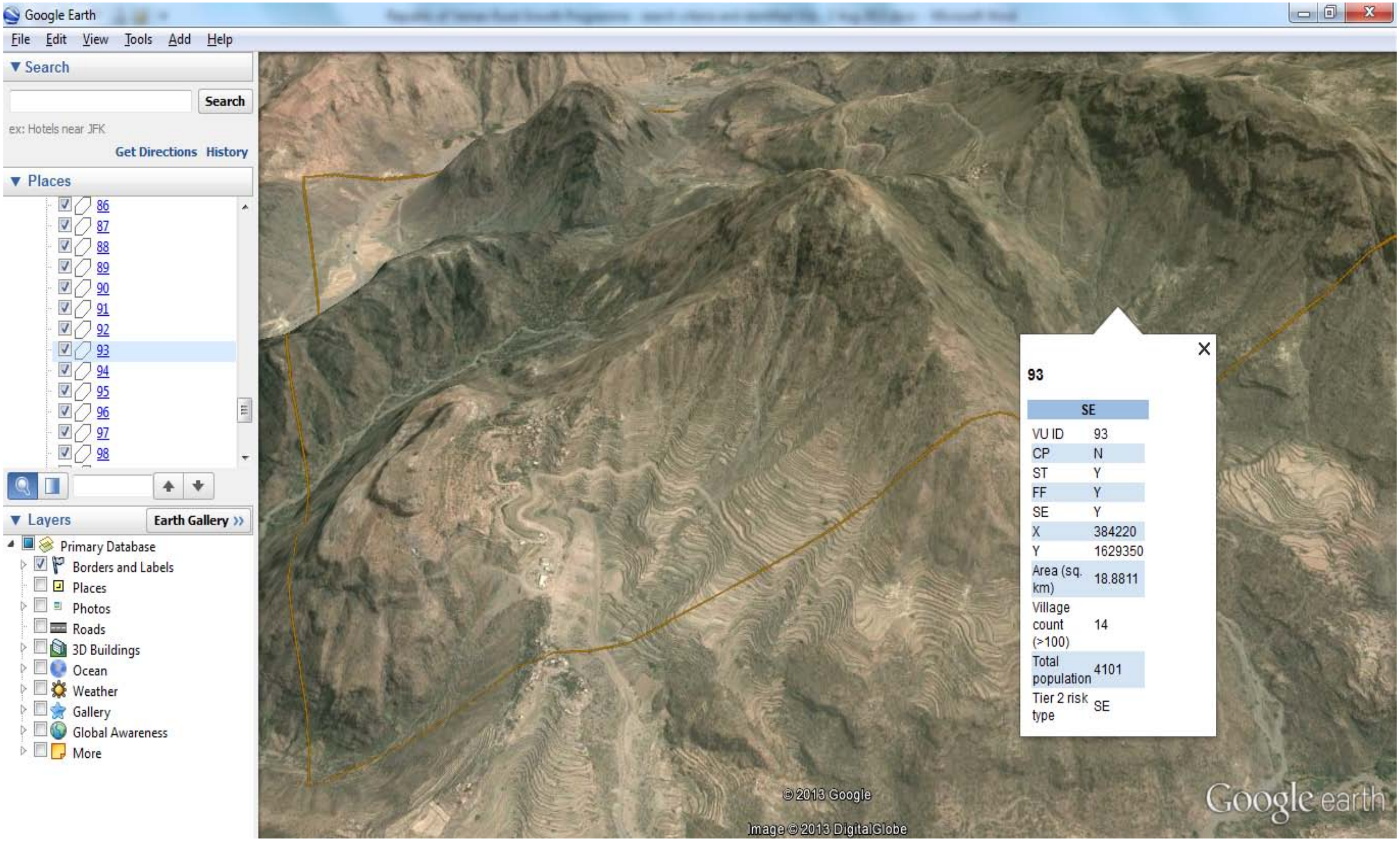
Add social vulnerability criteria

Tier 1	Tier 2
Village units: Selected sites should be close to a cluster of 3-5 settlements (~150 people) [2004 census]	**Village units**: As Tier 1 but smaller settlements included (~100 people)
Access: Settlements must fall within a 1 km buffer of a dirt road, and 10 km from a major urban area	**Access:** As Tier 1 but within 2 km buffer of a dirt road, and 15 km from a major urban area
Terrain: Preference for settlements in mountainous areas	**Terrain**: As Tier 1
Climate sensitivity: Settlements fall within climate hot-spot(s) for soil erosion, flash flood, water harvesting, and/or crop potential	**Climate sensitivity**: As Tier 1

Potential Village Units (VUs) Selected in Tier 2 Analysis (Taiz)



Google Earth tool



Screen shot from Google Earth tool demonstrating VU93 metrics in Dhamar.

Case study 2: Contextual climate vulnerability

Hydrology class Shanghai-style

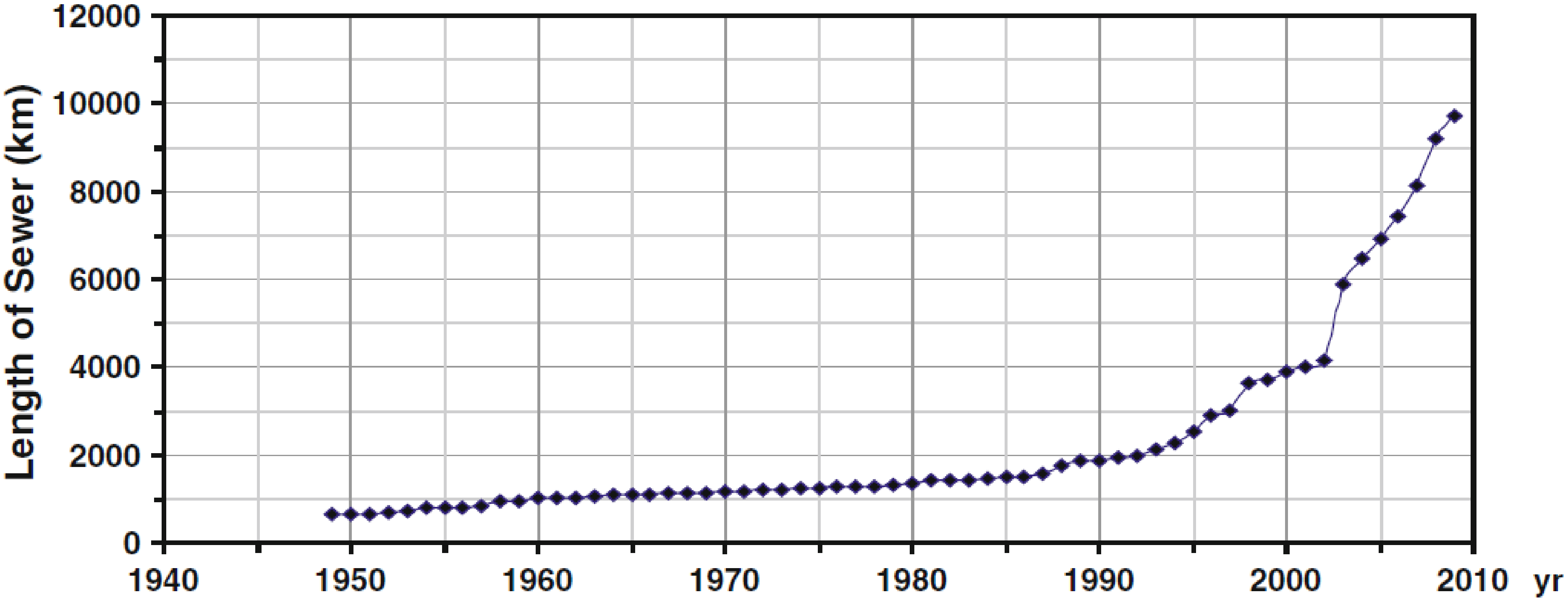
Waterlogging in inner-city Shanghai 1997-2011

Event	Rainfall (max)	Number of road sections waterlogged (water depth)	Number of houses inundated (water depth)
10 July 1997	51.5 mm/24 h	~60 (10–30 cm)	~1,500
10 June 1999	93.4 mm/24 h	163 (5–45 cm)	~2,500
30 June 1999	139.5 mm/24 h	~170 (5–30 cm)	~2,850
31 August 2000[a]	86 mm/24 h	More than 100	More than 3,000
23 June 2001[a]	200 mm/24 h	~50	More than 570
5–9 August 2001[a]	275 mm/24 h	476	47,797
27–28 August 2002	54.4 mm/24 h	~60 (5–20 cm)	More than 1,300 (5–10 cm)
22 August 2004[a]	83 mm/h	30	~700 (15–30 cm)
5–8 August 2005[a]	292 mm/24 h	187	~20,000
18 September 2007[a]	164 mm/24 h	128 (10–30 cm)	~8,035
25 August 2008[a]	117 mm/h	100 (10–40 cm)	~10,000 (5–10 cm)
10 July 2009	59.9 mm/24 h	~95 (10–40 cm)	More than 3,000 (5–10 cm)
1 September 2010	144.6 mm/24 h	More than 80 (10–35 cm)	~500 (10–20 cm)
12 August 2011	98.7 mm/h	~50 (5–40 cm)	~800 (10–35 cm)

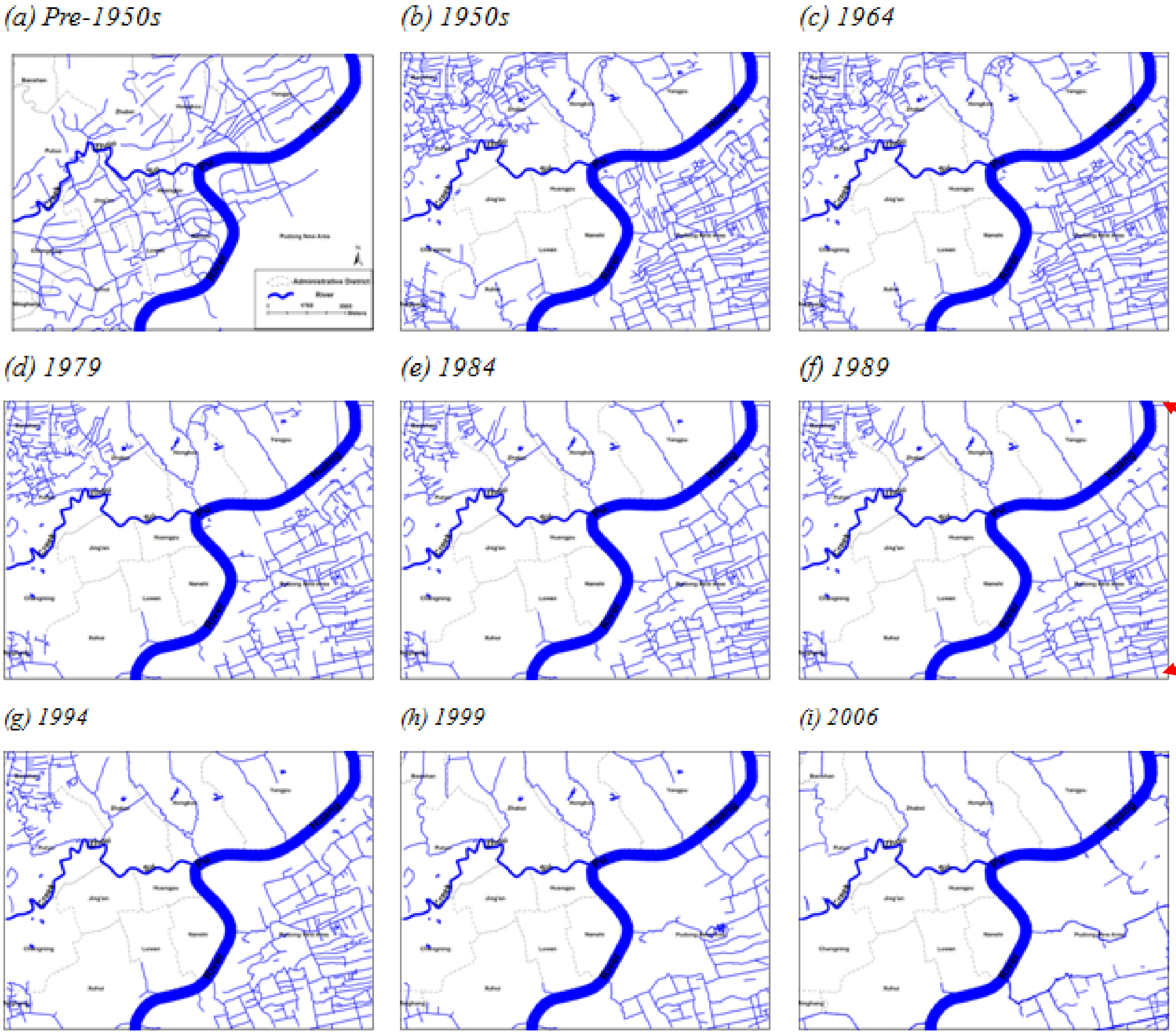
[a] Data taken from Shi et al. (2010)

Source: Wu et al. (2012) *Natural Hazards*, **63**, 305-323

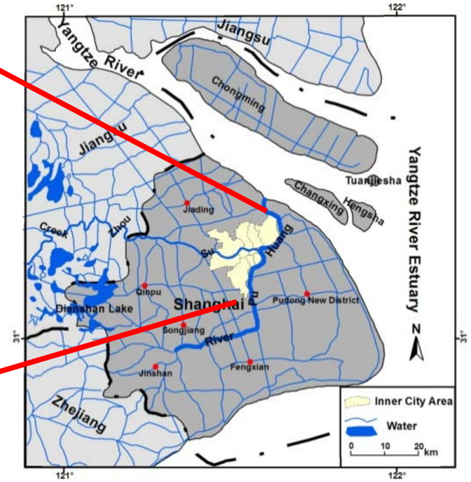
Sewer network expansion – paradox?



Length (km) of the urban storm sewer system in the City of Shanghai.
Note that the design standard is for rainfall with 6 month return period.

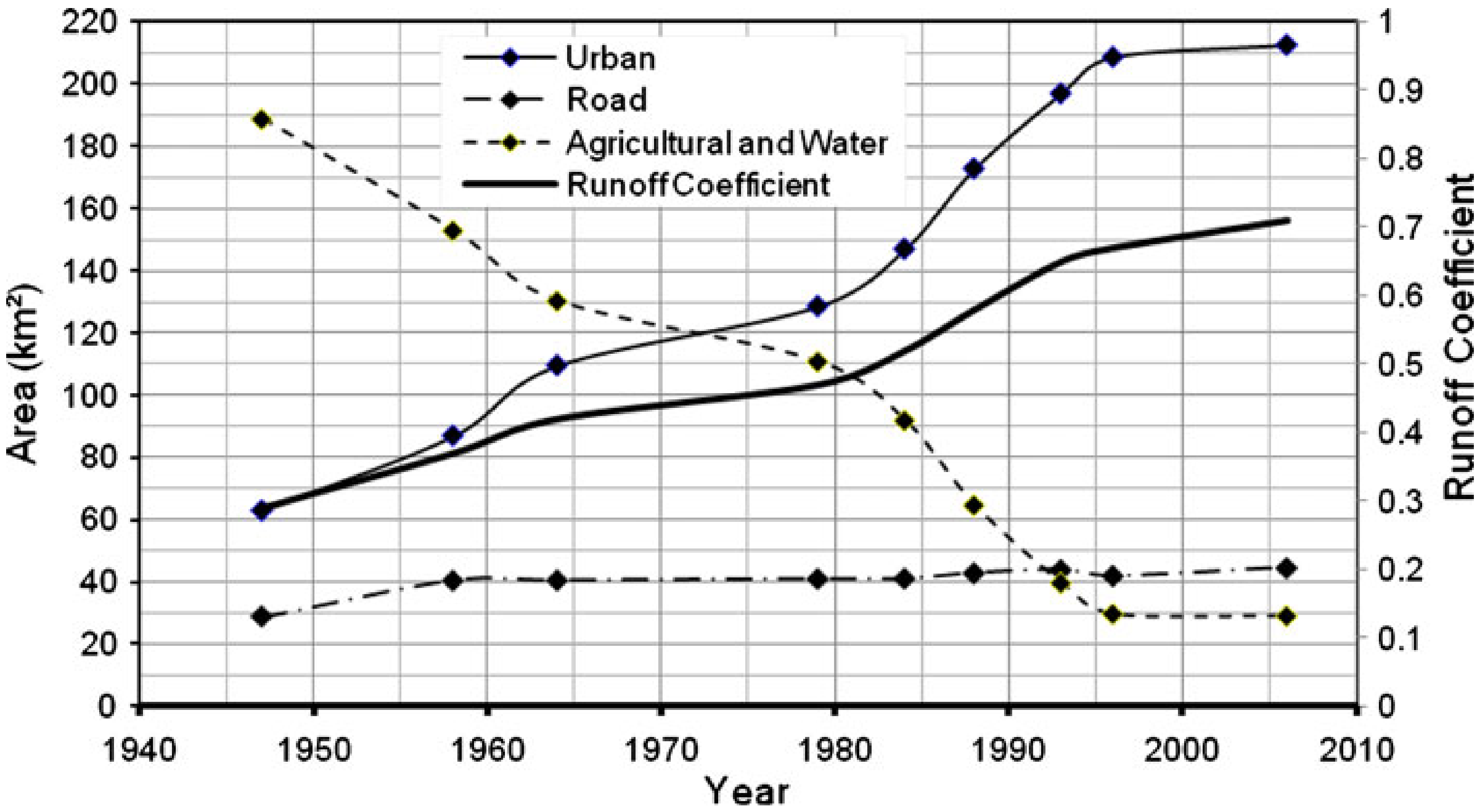


Shrinking 'natural' drainage



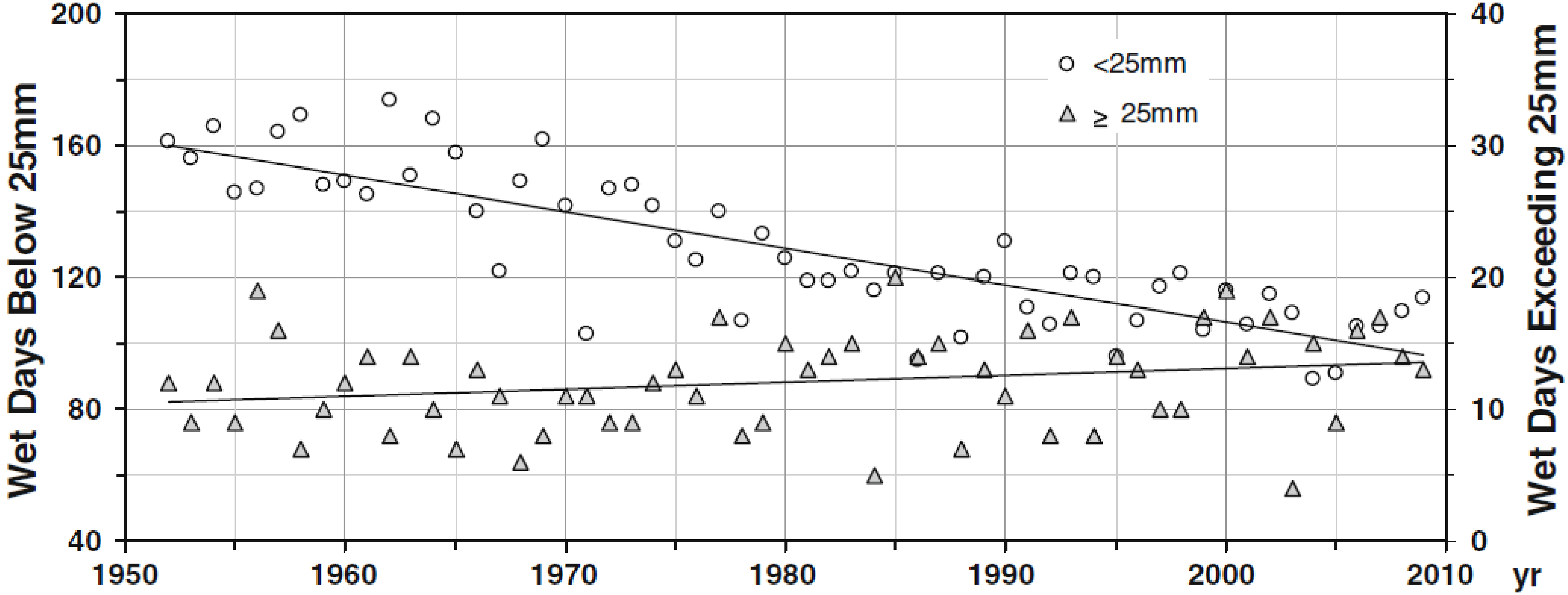
Total length of natural surface drainage in Shanghai has decreased by 270 km in 60 years

Land cover changes



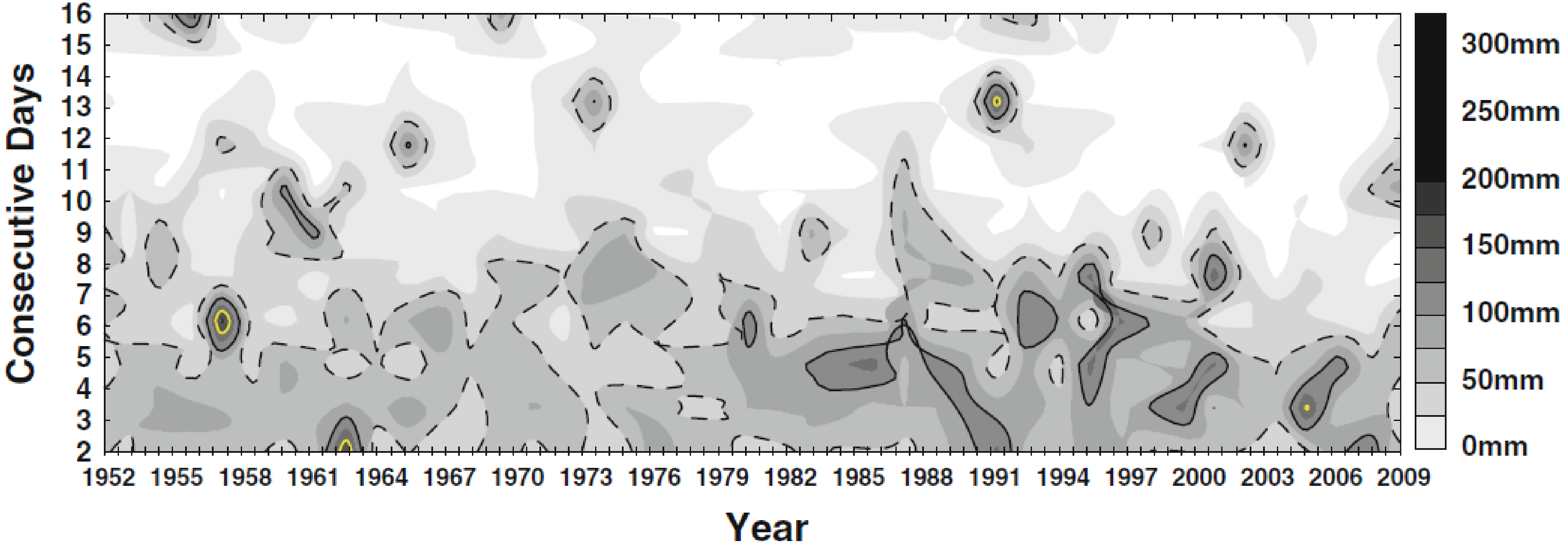
Evolution of (i) major land use types in Shanghai; and (ii) composite runoff coefficient for the City of Shanghai, calculated from standard runoff coefficients for different land use types (Standard of Storm Sewer Systems in Shanghai): agricultural (0.1); urban (0.8); and road (0.45)

Heavy rainfall events (24 hrs)



Annual number of wet days with precipitation below or exceeding 25 mm from 1952 to 2009

Heavy rainfall events (wet spells)



Maximum rainfall totals in Shanghai during 1952–2009 for clustering wet days (R2D–R16D). Consecutive totals exceeding 50, 100, and 150 mm are the regions enclosed by dashed, solid, and yellow lines, respectively.

Multiple interacting stresses

…It can be concluded that, in the past few decades, land cover changes, compounded by shifts in rainfall regime, have outpaced the development of the urban storm sewer system, increasing the risk of waterlogging in Shanghai…

Concluding remarks and research gaps

Conventional impact studies struggle to get beyond uncertainty (±42).

Gaps:

1. Decision-led frameworks for smarter use of climate information
2. Climate modelling agenda to meet key vulnerabilities
3. Models and field experiments to stress-test adaptation options
4. Simulation techniques for data sparse areas

Any questions?

Resources

Brown, C. and Wilby, R.L. 2012. An alternate approach to assessing climate risks. *Eos*, **92**, 401-403.

Pielke, R.A. Sr., Wilby, R.L., Niyogi, D., Hossain, F., Dairuku, K., Adegoke, J., Kallos, G., Seastedt, T. and Suding, K. 2012. Dealing with complexity and extreme events using a bottom-up, resource-based vulnerability perspective. In: Sharma, A.S., Bunde, A., Dimri, P. and Baker, D.N. (Eds.) *Extreme Events and Natural Hazards: The Complexity Perspective*, Geophysical Monograph Series, Vol. 196. American Geophyical Union, Washington DC, pp345-359.

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Wilby, R.L. and Yu, D. 2013. Rainfall and temperature estimation for a data sparse region. *Hydrology and Earth System Sciences*, **17**, 3937-3955.

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Loughborough University