

Exploring uncertainty in flood risk estimates using low-complexity modelling

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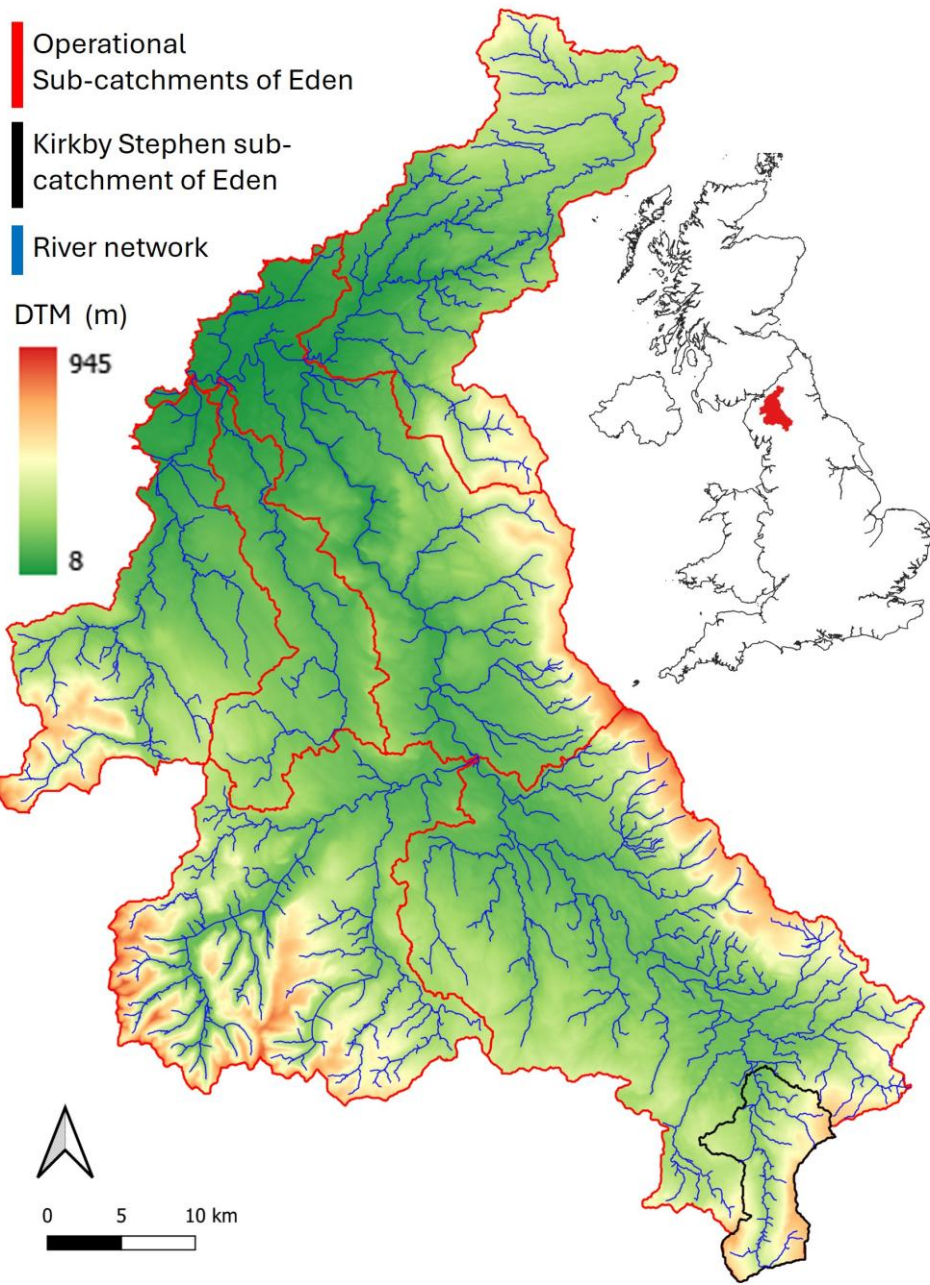
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Can we understand what drives flood risk uncertainty across catchments without repeatedly running expensive hydrodynamic models?

1. Case study: Kirkby Stephen

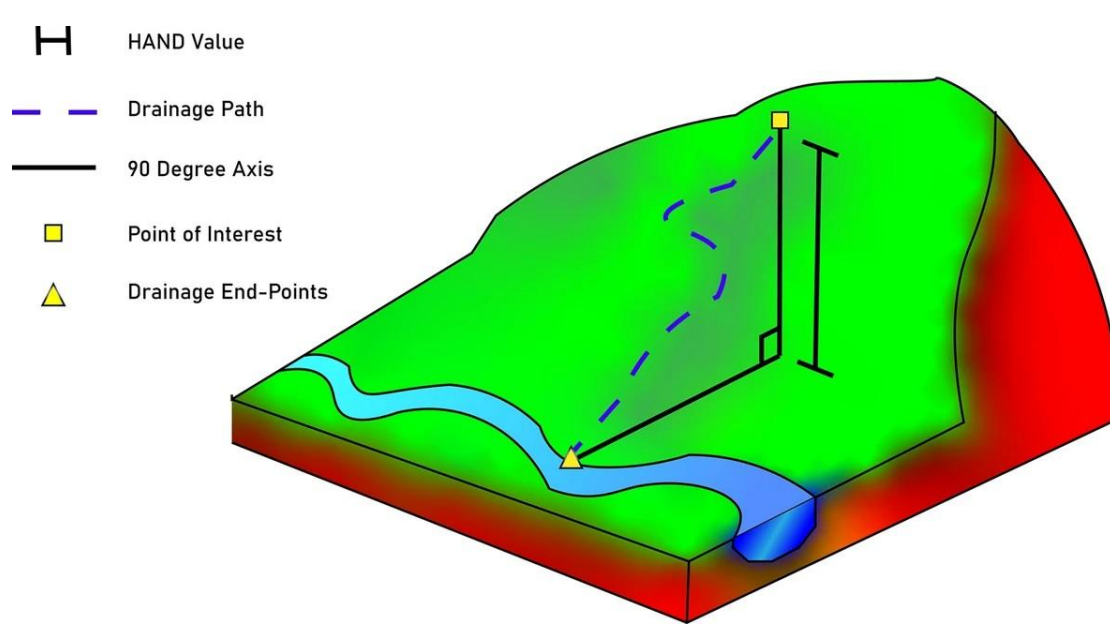


The *Kirkby Stephen* catchment, UK is used as the initial case study, combining information on flood hazard, exposure and vulnerability.

For each return period, we want to understand *where flooding occurs, what is exposed, and how much damage it causes.*

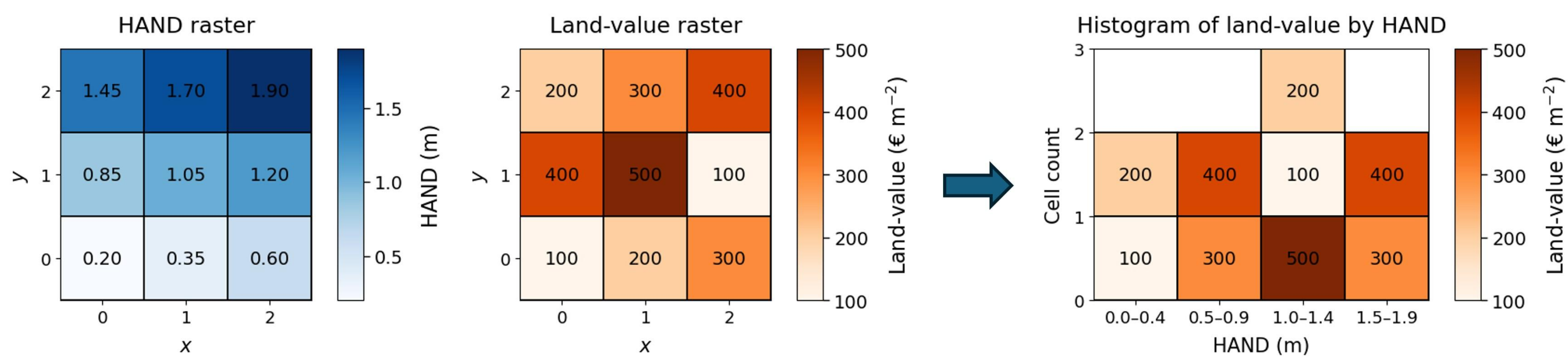
2. What if we reorganise the catchment by flood susceptibility?

Height Above Nearest Drainage (HAND) represents the elevation of each location relative to its connected drainage channel.



Reproduced from Scriven et al. (2021)

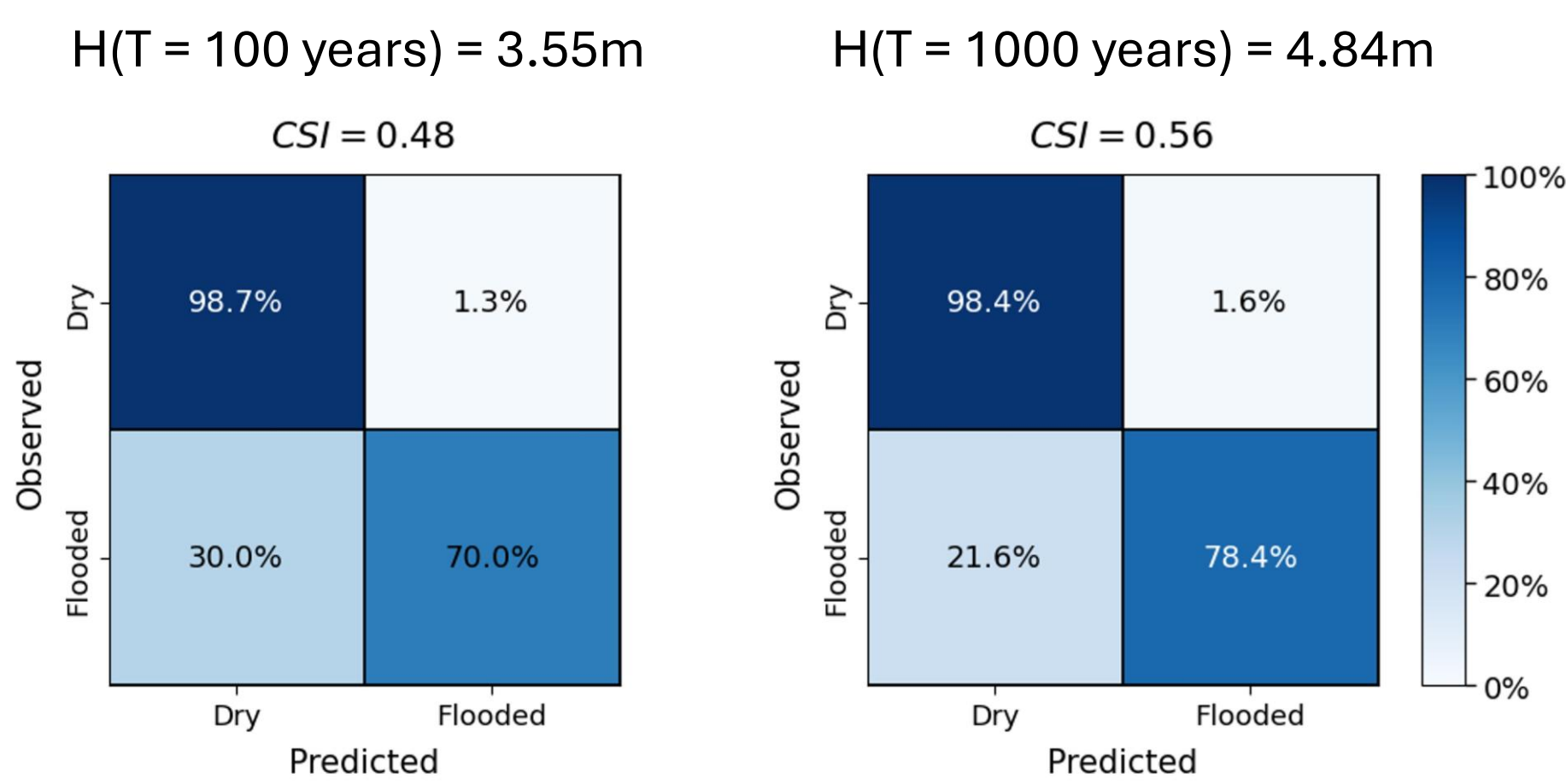
Instead of describing every cell by its geographical coordinates (x, y) , cells are organised according to their HAND elevation h .



This compresses the spatial representation while retaining information about *where exposure lie relative to the drainage network and potential inundation.*

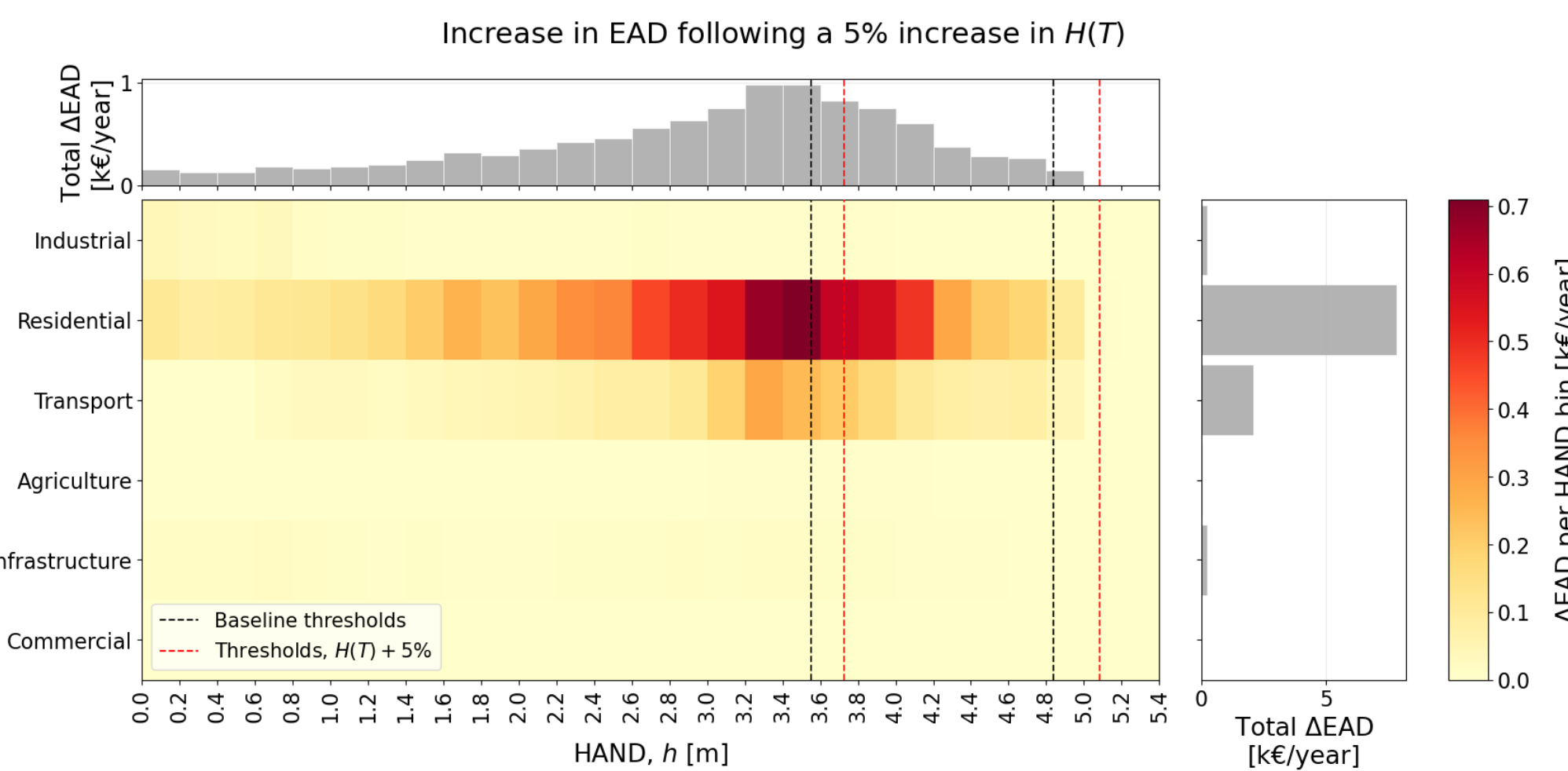
3. Connecting HAND to flood extents

Reference flood maps are used to identify the HAND threshold $H(T)$ that best reproduces the inundated area associated with each return period.



5. How uncertain is this estimate?

The calibrated HAND thresholds $H(T)$ are perturbed by $\pm 5\%$, representing *uncertainty in the relationship between flood frequency and inundation extent.*



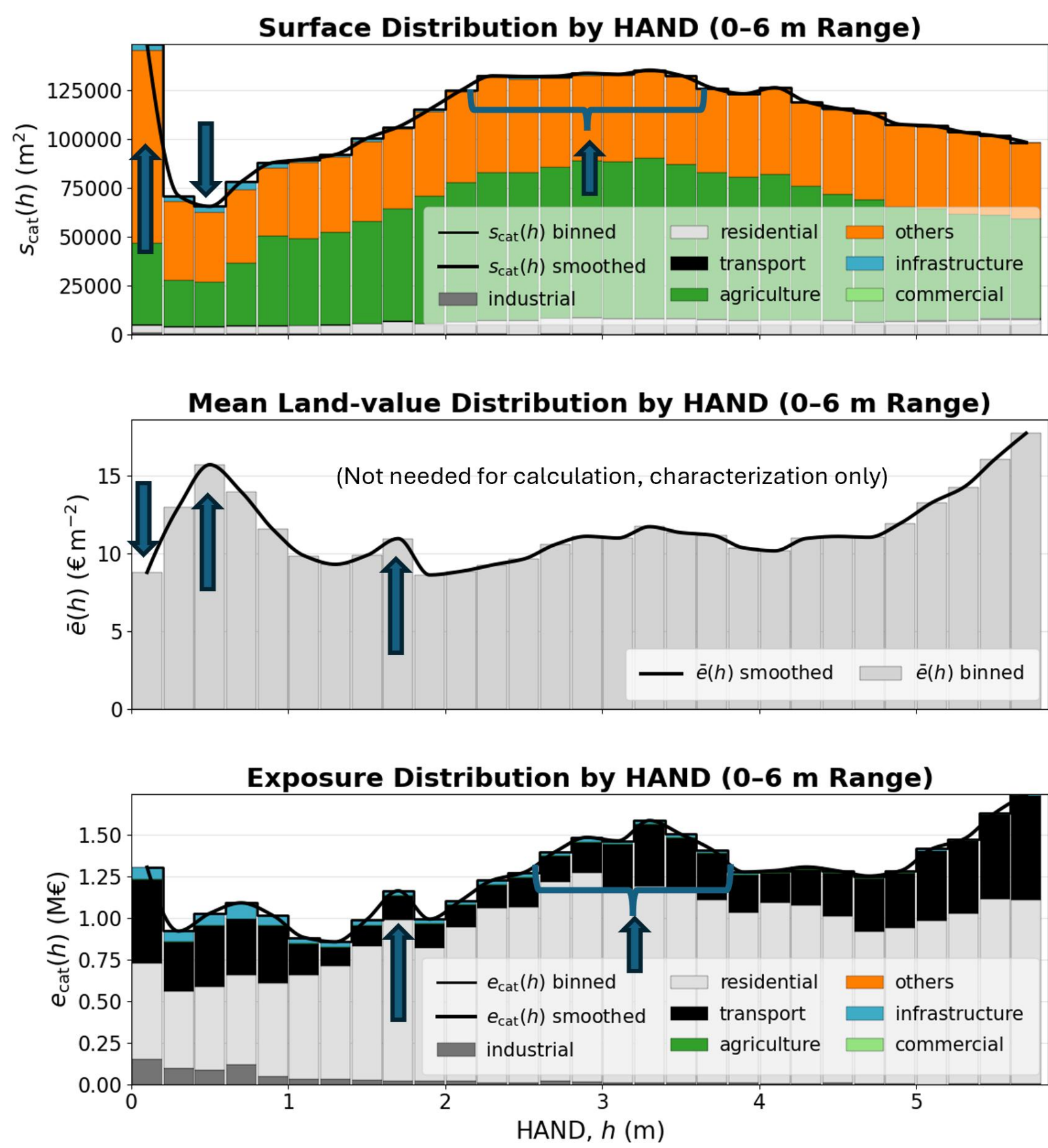
Land-use	H(T) - 5%		H(T) + 5%	
	ΔEAD (k€ yr ⁻¹)	ΔEAD (%)	ΔEAD (k€ yr ⁻¹)	ΔEAD (%)
Residential	- 7.62	- 9	7.84	9
Transport	- 2.03	- 6	2.07	6
Infrastructure	- 0.23	- 5	0.23	5
Industrial	- 0.24	- 5	0.24	5
Agriculture	- 0.04	- 9	0.04	9
Total	- 10.16	- 8	10.41	9

The HAND representation shows not only how much total risk changes, but *where the change occurs and which land-use categories contribute to it.*

4. What does flood risk look like along the catchment?

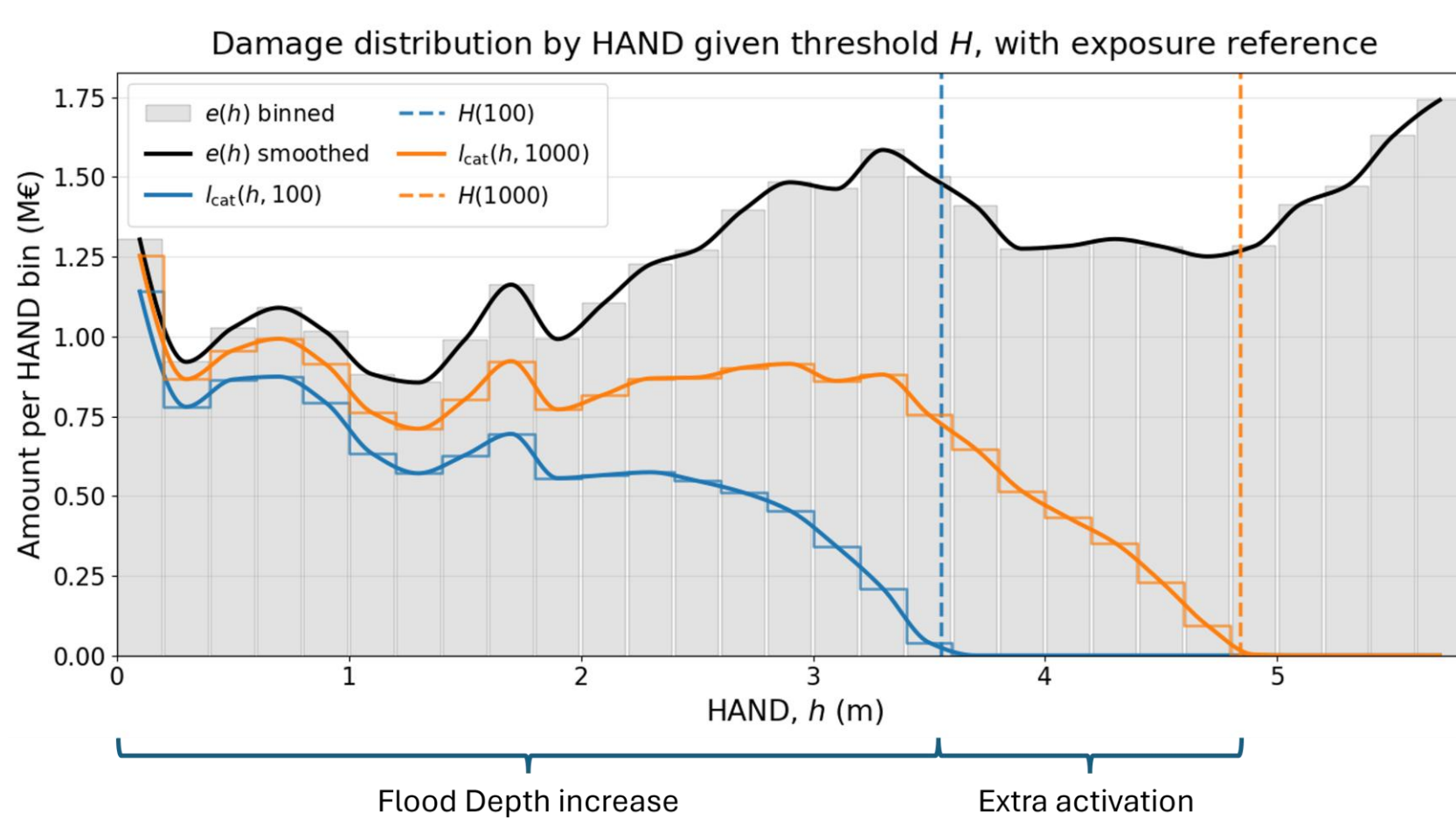
Once the catchment is represented over HAND, its *geomorphology, exposure and flood risk can be read along the same domain.*

1. What is exposed?



2. What is damaged?

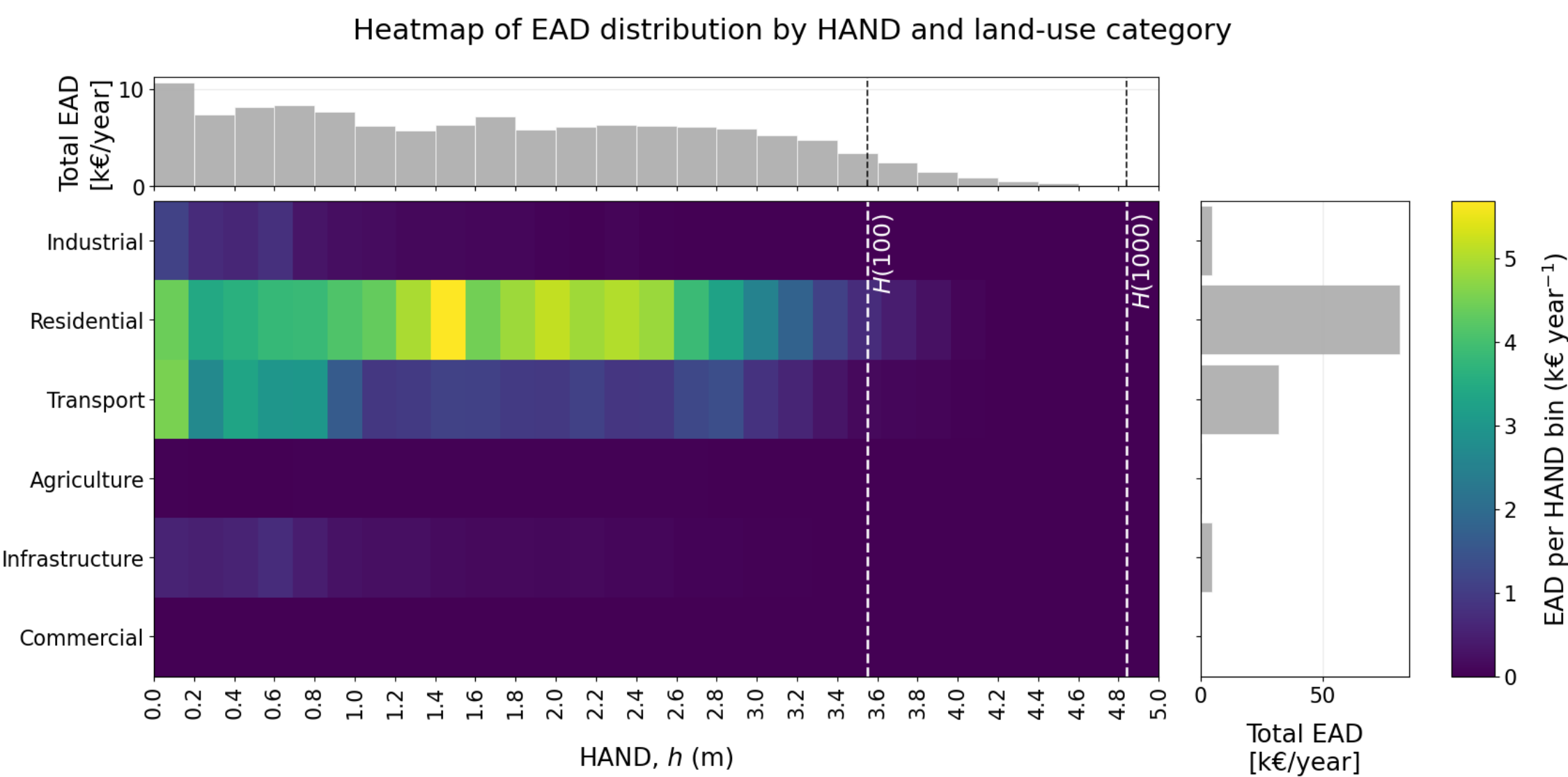
$H(T) \rightarrow$ flood depth $\rightarrow$ vulnerability & exposure $\rightarrow$ damage



100-year flood: €10.78 M
1000-year flood: €18.10 M

3. From damage across return periods to annual risk

Flood damages across return periods can be combined into Expected Annual Damage (EAD), providing a common *measure of flood risk.*



Land-use	EAD (k€ yr ⁻¹)	%
Residential	81.44	66
Transport	31.85	26
Infrastructure	4.72	4
Industrial	4.67	4
Agriculture	0.47	< 1
Total	123.15	100

6. Scaling up the analysis: more catchments and more uncertainties

Uncertainties across the complete flood-risk chain, including *hazard, exposure and vulnerability*, can be systematically perturbed to quantify how each propagates to flood-risk estimates. Applying the same methodology consistently across *multiple catchments* can produce comparable flood-risk and uncertainty profiles.

Comparing these profiles can reveal whether and how the sources and magnitude of flood-risk uncertainty differ between catchments, and which catchment characteristics may control these differences.

7. Current limitations

- Loss of hydraulic and spatial detail compared with hydrodynamic modelling.
- HAND performance varies with catchment characteristics.
- HAND derivation and catchment partitioning choices may influence results.

Reference

Scriven, B.W.G., McGrath, H. & Stefanakis, E. GIS derived synthetic rating curves and HAND model to support on-the-fly flood mapping. *Nat Hazards* **109**, 1629–1653 (2021).



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