Flash Flood Dynamics in Ireland: A Study of Two Irish Catchments using Remote Sensing and Hydrological Signatures

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BACKGROUND and MOTIVATION

- Flash floods are increasingly recognized as one of Europe's most destructive natural hazards, intensified by **land-use change, urbanization, and climate variability**
- Ireland's **contrasting rural and urban catchments** provide an ideal setting to explore how these drivers shape flood dynamics
- Understanding the links between **hydrological response**, **land-cover transformation**, and **extreme rainfall** is critical for local flood management and adaptation planning
- This study utilizes a **multi-data, multi-year analysis** in two Irish catchments — **Crookstown (agricultural)** and **Dodder (urban)** — during 2022–2024 hydrological year and develops a **Flash Flood Response Index (FFRI)** to understand the catchment's response in flash flooding scenario

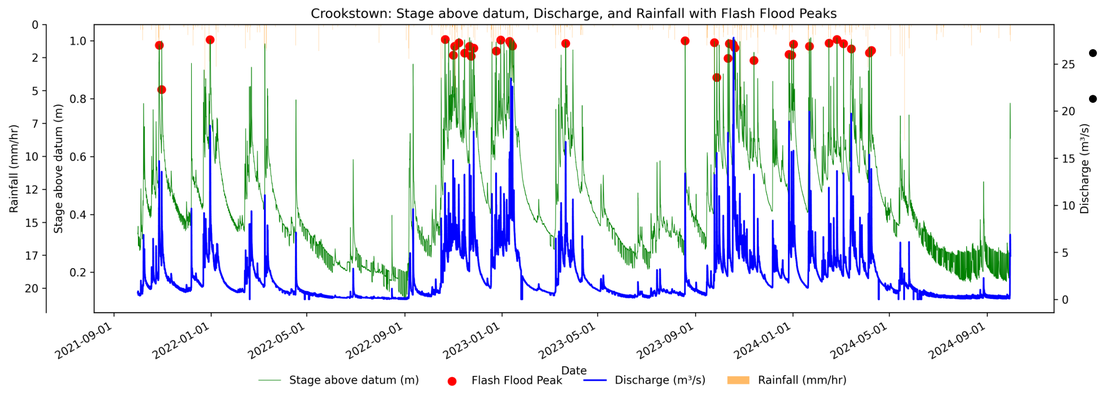

Fig 1: 2022-2024 Time series of Crookstown catchment showing Flash Flood events

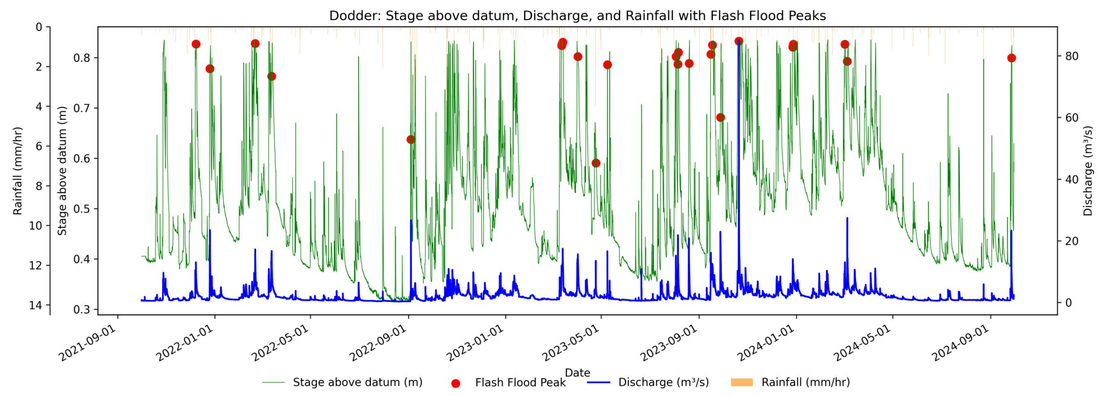

Fig 2: 2022-2024 Time series of Dodder catchment showing Flash Flood events

DATA and METHOD

- **Hydrometeorological Dataset** : Discharge and WL Data form 2022-2024 (Office of Public Works (OPW)), Rainfall data from 2022-2024 (Met Éireann)
- Flash flood events identification: a) Events were defined by flow peaks exceeding the **99th percentile of event-based discharge** b) These peaks were coupled with **a rapid rise time**, defined as an hourly increase above the 99th percentile and a minimum event interval of 1 hour or a rapid rise time relative to baseflow.
- Four Hydrological Signatures: **Lyne and Hollick Baseflow Index (BFI), Richards–Baker Flashiness Index (RBFI), Rainfall–Runoff Ratio (RR) and Elasticity Index (EI)** were calculated
- **Remote sensing** based **land-cover data** (Copernicus Sentinel-2 imagery). Three Land-cover indices were computed.
  - **NDVI** → Vegetation condition & infiltration potential
  - **NDWI** → Surface moisture & potential saturation
  - **NDBI** → Imperviousness & urban flood risk
- Land-cover classification using **Support Vector Machine (SVM)**
- Developed a combined Annual **Flash Flood Response Index (FFRI)**

Land-cover Classification using Support Vector Machine (SVM)

- Derived from resampled **10 meter 9 band Sentinel L2A** image of 2022, 2023 and 2024
- Supervised Classification using **70/30** train-test samples
- SVM classifier was trained on standardized spectral bands (B2-B11) and derived indices (NDVI,NDWI,NDBI)
- Model optimization employed a two-stage grid search over parameters C, γ, and kernel type (linear, RBF) with five-fold cross-validation to select the configuration yielding the highest classification accuracy
- SVM kappa **(κ) is 0.85-0.89 and SVM Overall Accuracy (OA) is 0.89-0.91**

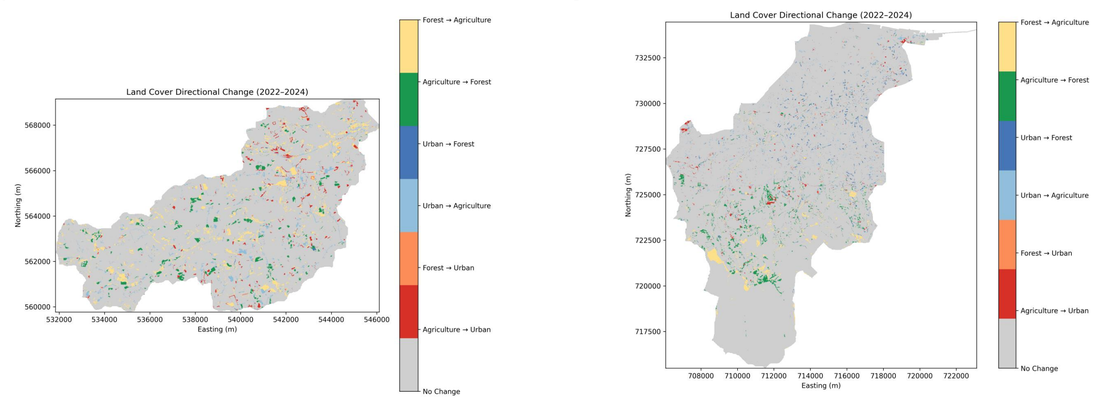

Fig 3: Land-cover transition from 2022-2024 (a) Crookstown (b) Dodder

RESULTS

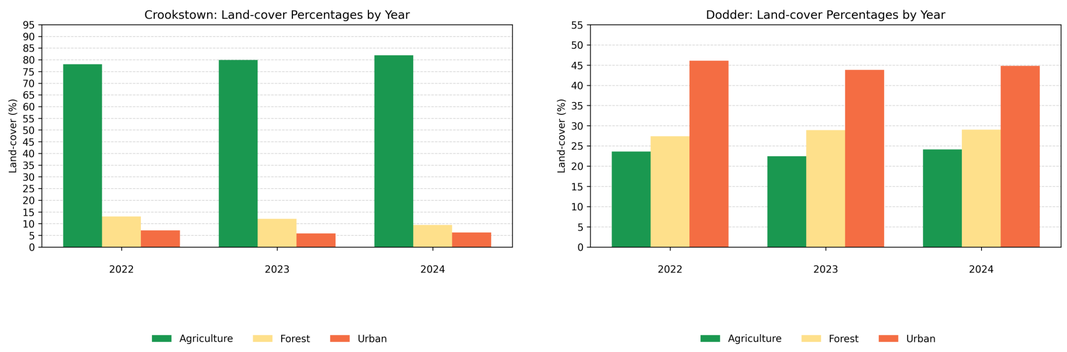

Fig 4: 2022-2024 Land-cover classification 9a) Crookstown, (b) Dodder

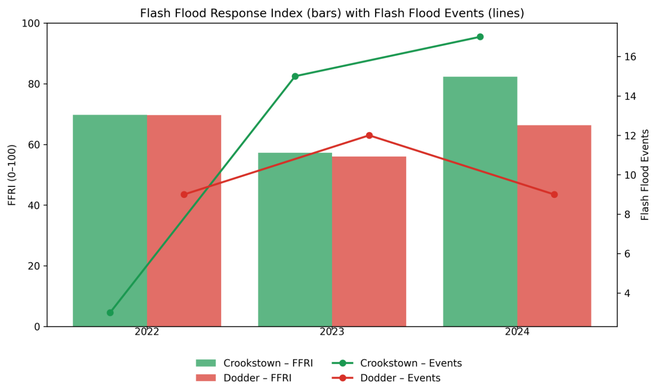

Fig 5: Annual Flash Flood Response Index Scores showing no of Flash Flood Events from 2022-2024

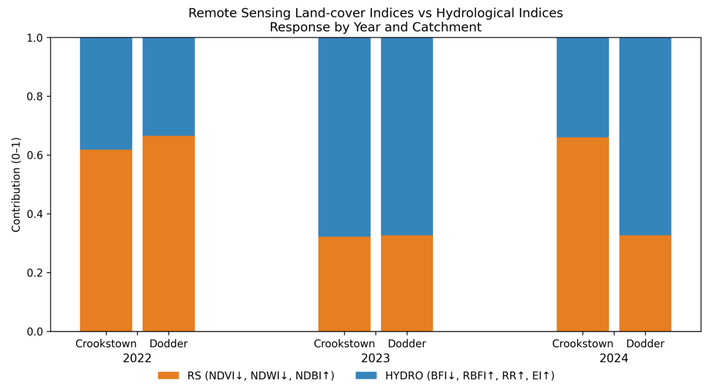

Fig 6: Comparison of FFRI performance between Hydrological Indicators and Remote Sensing Indicators

Table 1: Land-cover Indices, Hydrological Signatures and combined FFRI Scores for Crookstown Catchment

Crookstown Catchment

Year	Median NDVI	Median NDWI	Median NDBI	Base Flow Index	RB Flashiness Index	Rainfall Runoff Ratio	Elasticity Index	FFRI (%)
2022	0.53	-0.49	-0.16	0.1	0.03	0.66	1.36	69.72
2023	0.49	-0.42	-0.23	0.1	0.03	0.76	1.13	57.24
2024	0.52	-0.48	-0.15	0.11	0.04	0.89	2.58	82.29

Table 2: Land-cover Indices, Hydrological Signatures and combined FFRI Scores for Dodder Catchment

Dodder Catchment

Year	Median NDVI	Median NDWI	Median NDBI	Base Flow Index	RB Flashiness Index	Rainfall Runoff Ratio	Elasticity Index	FFRI (%)
2022	0.4	-0.39	-0.09	0.1	0.04	0.54	1.91	69.64
2023	0.35	-0.31	-0.13	0.11	0.04	0.58	2.12	55.98
2024	0.35	-0.31	-0.13	0.09	0.04	0.75	12.09	66.29

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DISCUSSION and CONCLUSION

- **In Crookstown**, flash flood events increased dramatically **3→15→17**, closely tracking increases in **RR (0.66→0.89)**, **EI (1.36→2.58)**. These changes coincided with significant land-use shifts such as declines in vegetation condition (lower NDVI) and evidence of agricultural expansion and forest loss which suggest reduced infiltration capacity, contributing to quicker runoff generation.
- The **Dodder catchment** exhibited more variable flash flood frequencies (**9→12→9**), but with pronounced sensitivity during major storm events, exemplified by the unusually high EI (**12.09**) during Storm Babet. The urban dominant catchment (**> 43%** area and moderate increases in NDBI) underscored the role of impervious surfaces in accelerating runoff and displayed a lower baseflow contribution (BFI) and higher flashiness (RBFI).
- **The Flash Flood Response Index (FFRI)** summarized annual catchment sensitivity by combining both **hydrological and remote-sensing indicators**, highlighting year-to-year variability and catchment contrasts. These findings emphasize the need for catchment-specific adaptation strategies, including land-use planning and targeted flood-risk management aligned with local hydrological response.

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