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Climate and environment

FlashFloodBreaker

Assessing the Impact of High-Resolution Hydrological Modelling on Streamflow and Flash-Flood Events in Crookstown Catchment, Ireland

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MOTIVATION AND METHOD

- Flash flood events have a very sudden impact on catchments, triggering a high volume of runoff in short period
- To understand the characteristics of the flash flood events (lag time, peak flow, time to peak etc.) we need to have detail information of the catchment land use, slope (derived from Terrain), channel and basin parameters
- SWAT+ has been used widely for long term streamflow modelling and forecasting but limited use for flash flood analysis
- Integrating 5m Digital Elevation Model (DEM), ML based 10m Sentinel- 2A Landcover classification and hourly precipitation input, SWAT+ hydrological model has been developed for Crookstown, Cork to capture extreme events

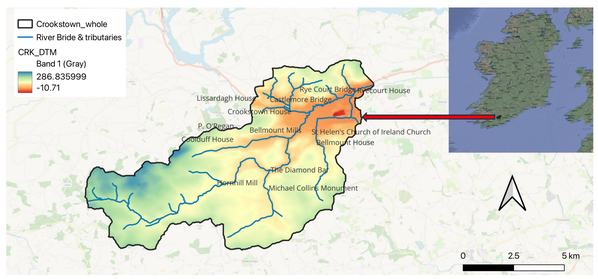


Figure 1: Study Area Crookstown catchment, 70.21 square km

Land-cover Classification using Support Vector Machine (SVM)

- Derived from 10m 9 band Level 2 Sentinel 2A image of 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 0.89 and SVM Overall Accuracy (OA) is 0.91

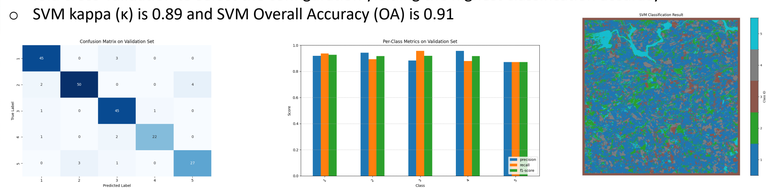
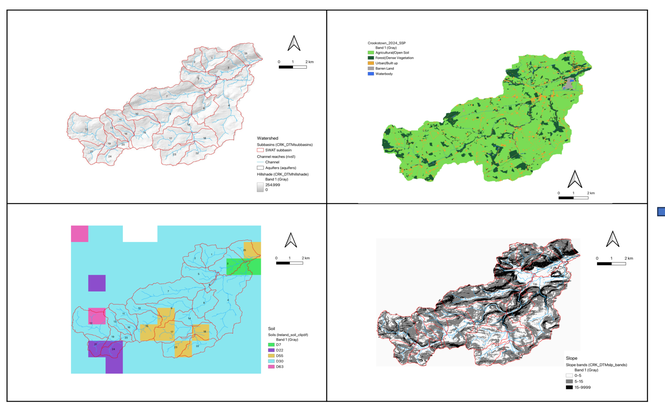


Figure 2:ML based land-cover classification for SWAT+ input

SWAT+ Modelling Key Setup Steps:

- Watershed delineation using 5m DEM
- **Land-cover** and soil classification
- HRU delineation
- Use **sub-daily rainfall & routing**
- Use **SCS-CN** or **Green–Ampt** infiltration method
- Adjust **SURLAG (Surface run-off coefficient)**, **CN2 (Curve number)**, **SOL_K (Soil hydraulic conductivity)** , **CH_N2 (Manning's n for channel)** for rapid response

Watershed + Land-cover + Soil class + Slope



Rural catchment, Dominant Baseflow

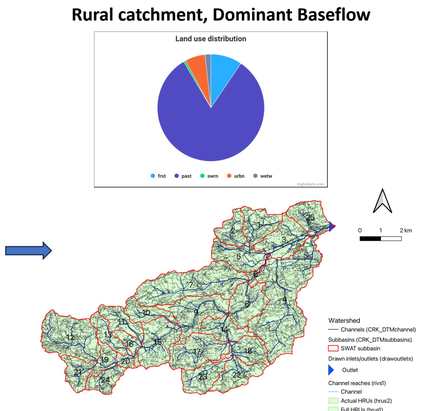
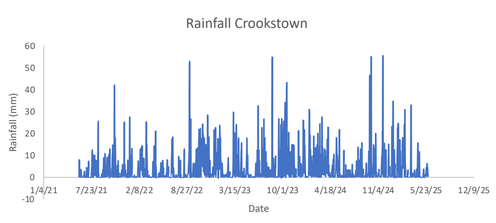


Figure 3 : SWAT+ Model Development Process; Data Preparation, Watershed and HRU Delineation

RESULTS

Observed Data (Office of Public Works (OPW) & Met Éireann



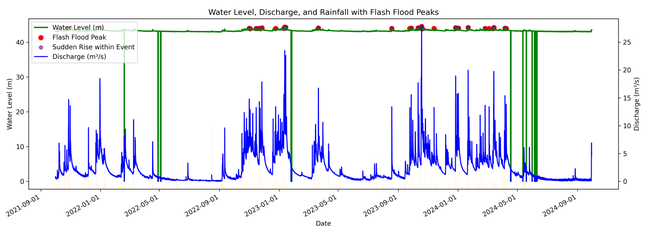
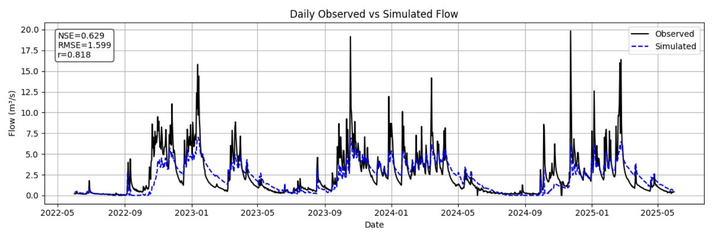


Figure 4: Rainfall, discharge and water level time series showing the high flow events for flash floods



Series1: daily_simulation-channel_sd_day-1-flo_out(m^3/s) Series2: observed-Flow R^2 = 0.67 (Pearson Correlation Coefficient = 0.82)
Series1: observed-Flow Series2: daily_simulation-channel_sd_day-1-flo_out(m^3/s) **Nash-Sutcliffe Efficiency Coefficient = 0.63**

Figure 5: SWAT+ model continuous simulation results for 2022-2025

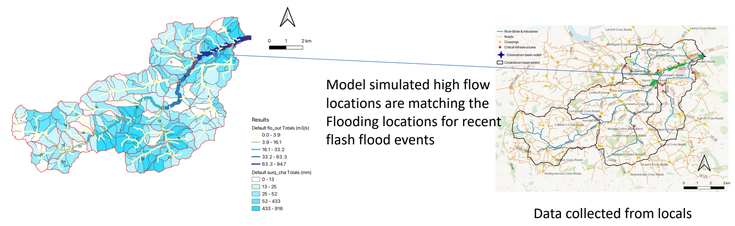
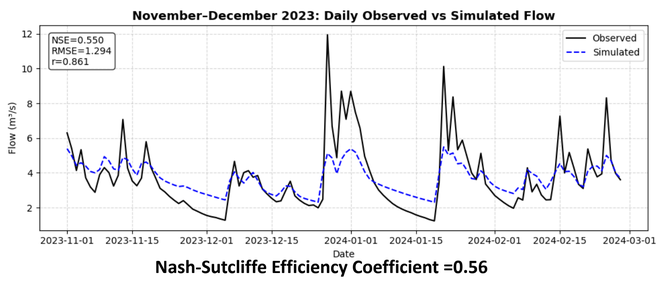


Figure 6: SWAT+ model simulation results showing high flow sub-basins and channels resulting in floods

Summary

- Streamflow predominantly driven by baseflow due to 81% pasture-land cover
- Curve Number and Soil Hydraulic Conductivity identified as most sensitive parameters
- Model shows moderate performance for long-term simulations
  - Accurately captures dominant flow pathways
  - Underestimates peak flow magnitudes
  - Lower accuracy in representing short-duration flash flood peaks
- Successfully identified flood-sensitive locations, validated by local stakeholders



Nash-Sutcliffe Efficiency Coefficient =0.56

Figure 7: SWAT+ model simulation results for high flow events

IMPACT AND RELEVANCE

- Demonstrates the **importance of high-resolution data** (DEM, land-cover, precipitation) in catchment-scale modelling
- Derived the **high-resolution land-cover map** for small basin of Crookstown, which is significant for Flash-flood mechanism in the catchment
- Continuous simulation of SWAT+ helps to calibrate the model and identify the **parameter uncertainty** which will be the main focus for transitioning to **event-based flash flood modelling**
- The sensitive parameters are identified which will drive the future model **calibration and validation**

CONCLUSION

The ongoing research and modelling activity provides insights for **flood risk management** and **land-use planning** in Irish basins. Furthermore, the approach of detailed flood modelling in HRU scale supports **stakeholder-driven decision-making** for **targeted mitigation** in vulnerable flood risk zones. In future, the model will uptake event-based simulation and forecast future events using **down-scaled climate and projected land-cover data**.

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